MATCHING-TO-SAMPLE IN YOUNG CHILDREN: EFFECTS OF THE NUMBER OF CHOICES ON MICROCOMPUTER PICTURE-WORD MATCHING

BY

PAMELA CAMPBELL

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TABLE OF CONTENTS

ACKNOWLEDGMENTS iii

LIST OF TABLES vii

LIST OF FIGURES ix

ABSTRACT xi

CHAPTERS

I INTRODUCTION 1

Background and Need for Study 2
Statement of the Problem. 10
Importance of the Problem 10
Nature of the Investigation 12
Questions Under Investigation 12
Delimitations of the Study 13
Limitations of the Study 14
Summary and Overview of Remaining Chapters . . . 14

II REVIEW OF THE LITERATURE 16

Selection of Relevant Literature 16
Overview of Matching-to-Sample 18
Learner Activity in Matching-to-Sample 22
Number of Matching-to-Sample Choices 41
Summary 81

III METHOD 82

Subject Description 83
Setting 85
Variables Under Investigation 86
Measurement 87
Experimental Design 90
Experimental Procedures. 91
Materials 96
Data Collection and Analysis 99
Summary 102

IV RESULTS. 103

Accuracy of Responding 103
Speed of Responding 112
Learning 116
Position of Response Choices 125
Maintenance 133
Summary of Results 152

V DISCUSSION. 154

Research Findings 154
Research Implications 170
Summary 183

GLOSSARY 184

REFERENCES 186

APPENDICES

A PERMISSION AND INFORMED CONSENT FORMS . . 199

B WORD RECOGNITION PRETESTS 203

C ENGLISH/SPANISH WORD LISTS 206

D PICTURE NAMING AND RECOGNITION PRETESTS . 212

E MATCHING-TO-SAMPLE PRETESTS 216

F DATA COLLECTION PROCEDURES 224

BIOGRAPHICAL SKETCH 228

LIST OF TABLES

Table		Page
2-1	Summary of Two-Choice Matching-to-Sample Studies	44
2-2	Summary of Three-Choice Matching-to-Sample Studies	63
2-3	Summary of Four-Choice Matching-to-Sample Studies	68
2-4	Summary of Five-Choice Matching-to-Sample Studies	70
2-5	Summary of Six-Choice Matching-to-Sample Studies	73
2-6	Summary of Eight-Choice Matching-to-Sample Studies	75
3-1	Subject Data	84
4-1	Differences in Accuracy of Performance Between Three- and Six-Choice Conditions	104
4-2	Differences in Speed of Performance Between Three- and Six-Choice Conditions	113
4-3	Differences in Movements per Minute Between Three-and Six-Choice Conditions	115
4-4	Celerations for Three-and Six-Choice Conditions	117
4-5	Percentages of Response Choice Positions	126
4-6	Differences of Response Choice Positions from Computer Standard	130
4-7	Summary of Experimental Phase Performances: Comparisons Between Conditions	131
4-8	Differences in Accuracy Between Three- and Six-Choice Conditions-Maintenance	134

Table		Page
4-9	Differences in Speed of Performance Between Three- and Six-Choice Conditions- Maintenance	137
4-10	Differences in Correct Movements per Minute Between Three- and Six-Choice Conditions-Maintenance	139
4-11	Differences in Proportion of Responses by Response Choice Position Between Three- and Six-Choice Conditions-Maintenance	141
4-12	Differences in Proportion of Responses by Position Between Phases	144
4-13	Response Choice Position Differences from Computer Standard-Maintenance	147
4-14	Combined Response Choice Position Differences from Computer Standard Across Experimental and Maintenance Phases	149
4-15	Differences Between Experimental and Maintenance Phase Performances	151

LIST OF FIGURES

Figure		Page
2-1	Linear two-choice pattern	28
2-2	Triangular two-choice pattern	28
2-3	Triangular/linear two-choice pattern	28
2-4	Rectangular two-choice pattern	29
2-5	Triangular two-choice pattern	29
2-6	Linear/random two-choice pattern	30
2-7	Linear/matrix two-choice pattern	30
2-8	Triangular three-choice pattern	31
2-9	Triangular/linear three-choice pattern	31
2-10	Circular/random three-choice pattern	32
2-11	Circular/lower three-choice pattern	33
2-12	Circular/pentagon four-choice pattern	33
2-13	Triangular/linear five-choice pattern	34
2-14	Circular five-choice pattern	34
2-15	Circular five-choice pattern	35
2-16	Rectangular six-choice pattern	35
2-17	Matrix eight-choice pattern	36
2-18	Circular eight-choice pattern	36
2-19	Frequency of matching-to-sample studies	79
3-1	Response Positions	89

Figure		Page
4-1	Subject 1: Accuracy of responding in the three- and six-choice accuracy conditions by sessions	106
4-2	Subject 2: Accuracy of responding in the three- and six-choice accuracy conditions by sessions	107
4-3	Subject 3: Accuracy of responding in the three- and six-choice accuracy conditions by sessions	108
4-4	Subject 4: Accuracy of responding in the three- and six-choice accuracy conditions by sessions	109
4-5	Subject 5: Accuracy of responding in the three- and six-choice accuracy conditions by sessions	110
4-6	Subject 6: Accuracy of responding in the three- and six-choice accuracy conditions by sessions	111
4-7	Subject 1: Differences in learning between three- and six-choice conditions	118
4-8	Subject 2: Differences in learning between three- and six-choice conditions	119
4-9	Subject 3: Differences in learning between three- and six-choice conditions	120
4-10	Subject 4: Differences in learning between three- and six-choice conditions	121
4-11	Subject 5: Differences in learning between three- and six-choice conditions	122
4-12	Subject 6: Differences in learning between three- and six-choice conditions	123
5-1	Hypothetical comparisons of speed and accuracy	161

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By

Pamela Campbell

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Matching-to-sample is an instructional procedure that has been used successfully across a variety of learners, settings, and instructional tasks. Despite the proven success of this procedure with the learning of new and abstract information, the effect of the number of choices on learner performance has not been systematically investigated.

In this study, three-choice and six-choice response conditions were manipulated to determine the effects upon accuracy and speed of responding, learning, and response choice position in a word to picture matching task. The investigation was replicated within six subjects and across two experiments. Comparisons were also made to determine whether observed effects on accuracy, speed of responding, and response choice position were maintained after an interval of noninstruction.

Given three choices, subjects demonstrated higher percentages of correct responses (accuracy) and greater numbers of correct responses per minute. The majority of subjects demonstrated greater learning (rates of improvement over time) with three choices. Little evidence of response choice position bias was noted. Although some performance losses were

noted, subjects generally maintained more efficient performances across measures when learning and maintenance phases were compared.

Three choices appear to be more appropriate than six choices for preschool-aged learners using this matching-to-sample procedure. Implications for researchers, instructional designers, and consumers are delineated with particular emphasis on the skills of young learners using the matching-to-sample procedure.

CHAPTER I
INTRODUCTION

Matching-to-sample is one instructional technology that has proven effective across many types of learners and has particularly interesting applications for handicapped learners (Etzel & LeBlanc, 1979; Mackay, 1985). In this procedure, a sample stimulus is presented and the learner is then able to select and match a response from alternative choices surrounding the stimulus.

As microcomputers have become an integral component in the educational process, matching-to-sample procedures formerly reserved for the research laboratory can now be immediately implemented in the classroom (LeBlanc, Hoko, Aangeenbrug, & Etzel, 1985). Microcomputers that use touchscreens for responding make it possible to implement precise and efficient matching-to-sample programs that are particularly appropriate for very young or handicapped learners (Rettig, 1986b).

Although various investigators have demonstrated the importance of the positioning of stimulus and response options and the degree of learner involvement, unanswered questions remain about the matching-to-sample procedure. It is important to

provide empirical answers for these questions before microcomputer programs are written with technical features that entrench less than optimal practices.

Whether learner achievement is a function of the number of response choices in a matching-to-sample procedure warrants investigation. In this study, the well-established teaching procedure of matching-to-sample was used to teach readiness skills to preschool students via the microcomputer. The effect that the number of choices presented during matching-to-sample tasks has on the acquisition of stimulus control was investigated.

Background and Need for Study

Learning Behavior

Skinner (1968) has defined teaching as the arrangement of reinforcement contingencies for tasks that are divided and reinforced in small steps. As a result, behavior can be maintained at given states of strength. Although researchers have been able to demonstrate the effectiveness of these principles in the operant laboratory, many teachers continue to provide instructional delays, inconsistent program sequences, a lack of progressive approximations to final behavior, and poor schedules of reinforcement (Skinner & Epstein, 1982). Reading, grammar, reading comprehension, and mathematics skills are all examples of important behaviors to which behavior technology has not been applied in a systematic and thorough manner. With microcomputers it becomes increasingly feasible to do so.

The Microcomputer

In less than 40 years, computer technology has progressed from large and inaccessible vacuum tube structures to small and accessible microcomputers, with learner-friendly software (Bramble & Mason, 1985). This increased accessibility is reflected in larger numbers of individual units in classrooms and concomitant growth in federally supported funding during the past 10 years (Moskowitz & Birman, 1985). Widespread computer availability has been the direct result of pressure from parents, administrators, and "grassroots" classroom experts to infuse computers into educational programming (Blaschke, 1985).

With advances pending in the areas of intelligent computing and artificial intelligence, educators are facing further instructional intrusions from electronic technologies. Teachers have had little time in which to evaluate the advantages and/or disadvantages of computer use as either an instructional or non-instructional tool. Were this trend to continue, the distinct possibility exists that instructional potential for computer instruction may go be unrealized by the classroom teacher.

Computers have been employed in the instructional setting both as an instructional vehicle and as a noninstructional tool for the management of instruction. Computer-Assisted Instruction (CAI) refers to the use of the computer to achieve a direct instructional

goal (Behrmann, 1984; Hagan, 1985). In accordance with the procedures for implementing effective teaching procedures (Englert, 1984), microcomputers can be used to individualize across ability levels and subjects through the systematic presentation of content, provision of immediate reinforcement, and recording of subject responses (Kameenui, Carnine, Darch, & Stein, 1986; Torgesen, 1986). Further, the use of the microcomputer as a delivery system and research tool eliminates the need for "experimenter-blind" conditions due to possible experimenter cueing effects.

Various types of CAI software programs have been developed and are generally categorized as simulations, drill and practice, games, or tutorial. Tutorial programs provide learners with opportunities to learn new concepts under the guidance and control of the computer program. Learner responses provide the basis for reinforcement and remediation (Kelly, Carnine, Gersten, & Grossen, 1986). In a similar way, matching-to-sample provides for the presentation of a stimulus and an opportunity for the learner to respond by selecting one of several response choices. Contingent upon correct responding, reinforcement or remediation is provided, followed by the presentation of the next stimulus.

Matching-to-Sample

Matching-to-sample provides the means for developing stimulus control for a variety of behaviors and is especially effective for complex and abstract behaviors (Ferster & Perrott, 1968). This

procedure has a lengthy history of proven success. In the 16th century, matching-to-sample was used by Itard to teach Victor, the Wild Boy of Aveyron, to match spoken words to objects and actions. Using auditory and visual discriminations embedded within chains of behavior, Victor learned to wait, look, and listen carefully in order to obtain food. The matching-to-sample procedure was used to extend communication skills to include his spoken name and finally the association of spoken words with pictures. Although Itard is often cited as being disappointed with the overall effects of the instructional program, Victor was finally able to name objects after matching-to-sample training (Stoddard, 1986).

More recently, both animals and handicapped learners have been used in laboratory investigations of behavior in which the matching-to-sample procedure has been utilized (Ferster & Perrott, 1968). Researchers have been successful in teaching pigeons to discriminate and reject defective drug capsules (Verhave, 1966) or to match playing cards to their corresponding suit name (Skinner & Epstein, 1982). Five- and 8-year-old autistic and retarded subjects have been trained via matching-to-sample to discriminate circles and ellipses with greater precision than Harvard graduate students (Sidman & Stoddard, 1967). Finally, when matching-to-sample techniques are used, learning can occur rapidly as learners

willingly persist at difficult tasks for long periods of time (W. D. Wolking, personal communication, April, 1987).

Because instruction based upon behavioral principles requires incremental sequential instructional steps and immediate reinforcement, elaborate equipment has been developed for use in laboratory settings. This equipment includes slide projectors, photocell response keys, and reinforcement dispensers. Implementation of effective technologies has subsequently been difficult for the individual classroom teacher. Based on the earlier work of Pressey, Skinner and Holland developed rudimentary teaching machines that presented information and provided opportunities for learner response and large numbers of very small reinforcers. Many educators, not understanding the purpose or potential role of such machines, resisted their placement in the classroom (Skinner, 1986). Although the effectiveness of the matching-to-sample procedure, both an instructional and as a record-keeping tool, has been documented, many researchers continue to use crude equipment of questionable reliability (Devaney, Hayes, & Nelson, 1986; Spradlin & Saunders, 1986) with which to implement the procedure. Those who have implemented electronic technologies have done so only in a peripheral manner and not for the purposes of providing instruction in a manner that is systematic and based upon effective instructional design principles. Academic reading, spelling, mathematics, and spoken language

skills have often been used as stimulus and response choices yet have not been investigated in a sequential and hierarchical manner (Spradlin & Saunders, 1986). Therefore, despite the proven success of matching-to-sample, relatively few studies exist with learners in actual classrooms.

The microcomputer can function as a tool to not only implement the matching-to-sample procedure as an effective teaching procedure, but also to examine procedural variables within the procedure that are manipulable. Simultaneous or delayed responding, the degree of learner activity, the arrangement of sample and response stimuli, or number of response choices are procedural variables that can be manipulated in order to systematically vary the matching-to-sample procedure.

In delayed responding, the sample stimulus is removed prior to the presentation of the surrounding matching choices and the learner is given the opportunity to remember. This type of format appears most suited for maintenance and retention of previously presented information. Delayed responding may not be most appropriate for the acquisition of new skills.

Learner activity can be increased by requiring the learner to point to the sample stimulus. In early studies with animals, birds did not demonstrate the strong behavior of looking at the sample. A separate reinforcer is required. By requiring the subject to touch the sample stimulus, attention is fostered and the likelihood

of control by the sample stimulus is increased (Skinner & Epstein, 1982). Skinner has suggested that humans, monkeys, and apes are reinforced simply by the ultimate success potential provided by choosing (Skinner & Epstein, 1982). However, preattention skills are often the concern of educators of young children or those with immature attending skills. The use of the matching-to-sample procedure of touching the sample stimulus, together with the technology of the touchscreen and the microcomputer, has been suggested by Rettig (1986a) as the most efficient teaching strategy for learners with young mental ages.

Sample and matching choices can be arranged in a variety of patterns. In many of the early studies, pigeons were required to peck keys on the left or right of the sample (Ferster & Perrott, 1968). In early studies with humans, a sample stimulus was presented in the center of either a 3x3 array or circular pattern (Sidman, 1971; Sidman & Stoddard, 1967). Patterns and stimuli arrangements of stimuli can also be varied to provide the opportunity for alternative numbers of response choices. Numbers of choices have ranged from two to eight. Sidman has supported the notion that more than two choices are needed but exactly how many remains unclear (personal communication, October 29, 1986). Standard descriptions of matching-to-sample describe general procedures for the sequence of sample stimuli and reinforcement schedules yet fail to address the issue of numbers of choices (Sulzer-Azaroff & Mayer, 1977). Engelmann

(cited in Becker, Engelmann, & Thomas, 1975) has demonstrated a precise structure for the systematic and cumulative variation of alternatives in which all relevant and irrelevant characteristics of the positive and negative stimuli are presented in two-choice discrimination . Engelmann and Carnine have also stated that learners can process up to 11 items on a page (Engelmann & Carnine, 1982), while Woodward (1987) has suggested no more than 10. Miller (1968) has affirmed that learners can recall or efficiently use up to 7 individual pieces or clusters of information. Thus, although effective learning has been demonstrated using each of the above formats, some question remains as to the most efficient and effective number of choices for learners at specific ability levels or learning phases.

Summary

The matching-to-sample procedure is an instructional format that is well-suited to the presentation of new and complex concepts. With the microcomputer, instructional procedures can be implemented in a consistent, reliable, and efficient manner according to the needs of the individual learner. The combination of matching-to-sample and the microcomputer in classroom settings can provide rapid access, consistent presentation, and reliable recording of the accuracy, speed and position of learner responses to an efficient instructional procedure.

Statement of the Problem

Although matching-to-sample has been demonstrated over time to be an effective and efficient instructional technique, the application of this procedure to the classroom has been limited. Concurrently, a number of procedural variables in the matching-to-sample procedure have not been systematically investigated. The rapidly expanding capability of the microcomputer has occurred simultaneously with the placement of increasing numbers of microcomputers in classrooms. The potential therefore exists for the implementation of instructional programming, including matching-to-sample, that is neither well-designed nor appropriate for the learner.

Importance of the Problem

1C - Why is your problem an important one to study?

The problem of measuring and documenting the details of performance in stimulus discrimination via matching-to-sample procedures is important for several reasons. First, the success of the matching-to-sample technique as an instructional technique has been demonstrated and replicated with animals and human learners; yet, investigators have failed to address the effectiveness of the numbers of response choices. Second, applied research in the classroom setting has been limited due to the need for costly equipment and time-consuming investigatory procedures. Descriptions of learning performances by the average or mildly handicapped learner using matching-to-sample have not been generally available. Third, the technology

exists or is potentially available in most classrooms to implement a strategy that is similar in design and purpose to that proposed in this study. Fourth, the abilities to attend, discriminate, and match stimuli are considered important skills in the acquisition of readiness skills and have been linked to student achievement in both regular and special education. Fifth, Engelmann and Carnine (1982) have outlined the systematic presentation of non-examples as well as examples during the acquisition stage of learning. Further information is needed as to both the role and the numbers of non-examples in learning tasks with more than two choices. Sixth, many learners of elementary school age have persistent and resistant problems with stimulus discrimination. Stimulus discrimination requires that the learner respond accurately even when another stimulus with similar physical properties or previous stimulus association is presented. According to Pryor (1984), stimulus control is demonstrated when the learner responds appropriately only in the presence of the specific stimulus, never in the presence of an alternative stimulus, never in the absence of the specific stimulus, and never with an alternative response in the presence of the stimulus. Methods for developing stimulus discrimination have included two-choice discrimination and matching-to-sample procedures. Seventh, given the current emphasis on the identification and development of programs for young learners with special needs, procedures with demonstrable effectiveness are needed and the

matching-to-sample procedure can provide such demonstrations. This study may provide a foundation upon which to build a feasible and reliable instructional strategy with applicability to students of varied ages and discriminative ability. The results of this investigation should add to the developing body of knowledge on the technology of teaching.

Nature of the Investigation

The number of response choices in the matching-to-sample procedure is a manipulable variable that has not been systematically studied and is in the early phases of investigation. This study was therefore exploratory to determine whether the notion of learner differences based upon the number of choices is sensible and, if so, whether differences are large enough to recommend additional research or alternative matching-to-sample teaching procedures. The single subject experiment by design permits and accounts for the amount and nature of any performance differences.

Questions Under Investigation

This study was conducted to examine the effect that the number of choices has on the ability of the student to learn and develop stimulus discrimination. Two conditions were systematically manipulated in the context of matching words to pictures by preschool-age learners. The number of correct and error responses, response time, and response position were recorded under both conditions for each subject. The following question was addressed: Are there differences in learner

performance in a three-choice as compared to a six-choice condition? In addition, five related questions were investigated. Does the number of response alternatives affect learning accuracy during the acquisition of stimulus control? Does the number of response alternatives affect speed of responding during the acquisition of stimulus control? Does the number of response alternatives affect celeration (rate of learning or improvement) during the acquisition of stimulus control? Does the number of response alternatives affect response choice position during the acquisition of stimulus control? Does the number of response alternatives affect learning performance during the maintenance of stimulus control? Maintenance of stimulus control was determined by a single measurement of learning accuracy, learning speed, and response choice position.

Delimitations of the Study

This study was delimited in several ways. The investigation was conducted in Alachua County, a medium-sized county in north-central Florida. The subjects for this study were of preschool age, not diagnosed as handicapped, and selected from a preschool in Gainesville, Florida. Additionally this study involved only subjects whose parents who volunteered to permit their children to participate in this research project. There was no consideration given to the sex or socioeconomic status of the subjects. The tasks employed for instruction in the individual learning trials for this investigation constituted a further delimitation.

Limitations of the Study

Several limitations were imposed that may restrict the generalizibility of the findings. Specific eligibility or entrance criteria used at the Baby Gator Preschool may limit the generality of findings to other preschool settings. Since the learners in this study were selected from a preschool program, generalization to grade levels in which younger or older students are enrolled should be made with caution. Further, results may not be generalized to either older or younger students or to those individuals diagnosed as handicapped, without systematic replication with samples from those populations.

Summary and Overview of Remaining Chapters

The effects of three- and six-choice alternatives in a matching-to-sample procedure were addressed in this study for the purpose of identifying whether one condition is more effective in the acquisition and maintenance of picture/word matching skills among preschool learners. Empirical evidence linking this variable via computer instruction is lacking in both regular and special education. This investigation was designed to further define the components of the matching-to-sample procedure via the microcomputer.

In Chapter II, a review and analysis of pertinent matching-to-sample studies are presented with emphasis on the following: learner activity, the arrangement of sample and matching stimuli, and the number of response choices. The implications of previous research for educators of preschool and special education students are discussed in light of the present study. In Chapter III, the procedures used in

investigation are described and, in Chapter IV, the obtained results are described. Finally, a discussion of the results in terms of current knowledge, implications for future research, instructional designers, is and classroom implementation are presented in Chapter V. Definitions of terms used in this investigation are presented in the Glossary.

CHAPTER II
REVIEW OF THE LITERATURE

The purpose of this chapter is to synthesize existing literature related to manipulable procedural variables of the matching-to-sample procedure. Examples of procedural variables are the relative position of sample or choice stimuli, the size of the choice stimuli, or the time between presentation of the stimulus and the choice stimuli. These variables may require definition and description in order to attribute results to independent variables or to the matching-to-sample procedure itself. Criteria for inclusion in this review are stated first, followed by a discussion of learner activity as it relates to matching-to-sample. This chapter concludes with a review of matching-to-sample studies according to the numbers of choices provided the learner.

Selection of Relevant Literature

The selection of relevant literature for inclusion in this study required the delineation of selection criteria. The goal of the review was to examine matching-to-sample studies in which descriptions of manipulable variables have been included. Further, literature related to the activity of the learner when participating in the matching-to-sample procedure was reviewed.

All relevant research published in the last 20 years (1967-1987) as well as other important investigations or findings prior to that period of time were reviewed. Reference sections from related articles, chapters, and books reviewed were sources for locating less recent research. Studies that used the matching-to-sample procedure had to meet the following criteria for inclusion in this review:

1. Some aspect of learner behavior was included in the dependent measure.
2. A description of the numbers of stimulus and response choices was included.
3. A description of the arrangement of the stimulus and response choices was included.
4. A description of learner activity was included.

Sources reviewed included Current Index of Journals in Education (CIJE), Education Index, Knowledge Index, Educational Resources Information Center (ERIC), Library User Information Service (LUIS), card catalogs at the University of Florida libraries, and personal communication with professionals in the fields of special education and matching-to-sample research. Descriptors used for the literature search included matching, sample, matching-to-sample, attention, preattention, stimulus control, effective learning, and learner responses.

Certain criteria were applied to the studies located in the initial search to ensure that only methodologically sound studies would be

included in the literature review. These criteria were as follows:

1. The subjects and setting for the study were thoroughly described.
2. The dependent variables, procedures, and materials were thoroughly described.
3. The data display and analysis were presented without significant losses of information.
4. The investigator's conclusions were consistent with the results displayed.

Forty-two matching-to-sample studies were reviewed. Because one study incorporated two different numbers of choices within the same study, this review actually encompasses 43 studies. Only one study was located in which a matching-to-sample procedural variable related to numbers of choices was investigated.

Overview of Matching-to-Sample

The matching-to-sample procedure has been studied and implemented successfully across a wide spectrum of learners and learning activities. Studies with nonhuman learners such as pigeons (Cumming & Berryman, 1965; Verhave, 1966),and monkeys and baboons (Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982) have been and continue to be conducted in laboratory settings. Studies with human learners have been conducted both in the laboratory and in classrooms with retarded children and adults (Sidman, 1971; Sidman & Cresson, 1973; Sidman, Kirk, & Willson-Morris, 1985), normal learners (Lazar &

Kotlarchyk, in press), preschoolers (Lahey & McNees, 1975), adolescents (Sidman, Cresson, & Willson-Morris, 1974), college students (Skinner, 1968), and adults (Lazar, 1977).

Matching-to-sample has also been used successfully to teach a variety of tasks. Simple discrimination tasks such as identity matching (Carter & Eckerman, 1973; Sidman, 1971), as well as complex concepts and symbolic tasks (Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982) have been taught with high accuracy and efficiency. The procedure has also been used successfully to teach spelling (Mackay, 1985) and reading comprehension (Sidman, 1971).

As the matching-to-sample procedure has evolved in the past 30 years, techniques for implementing the procedure have changed in ways not necessarily related to substantiated findings of increased effectiveness. Initial studies in which matching-to-sample was used were conducted with animals in specially constructed chambers. As a result of these early studies, more sophisticated laboratory equipment that could deliver greater numbers of alternatives in a wider variety of formats to both human and nonhuman learners was designed. The teaching machine was developed in an attempt to translate the matching-to-sample technique into a teaching technology that could be implemented in applied classroom settings. Resistance from educators resulted in the continued use of flashcards, semi-automatic machines, and other crude and less reliable methods of

implementing matching-to-sample procedures classroom settings.

The ability of technologies to deliver more sophisticated patterns has dictated the format of certain procedural variables. In laboratory studies, the matching-to-sample procedure has been continually refined electronically without certain procedural variables being systematically challenged and investigated. Because the microcomputer is now capable of delivering sophisticated and reliable matching-to-sample procedures in the classroom in an atmosphere of ready acceptance and high motivation (Serna, 1987), a determination of procedural variables is needed to reduce the possibility of misinterpretation and inefficient learning.

Cumming and Berryman (1963) suggested three classes of matching-to-sample procedures that can be manipulated and therefore warrant investigation. The first category, reinforcement contingencies, that govern the effects of responses to either the choice or comparison stimuli, has been studied by Verhave (1966) and Sidman and Stoddard (1967). The second variable, the temporal relations between the choice and comparison stimuli, has been the subject of studies by Sidman (1969) and Nelson and Wasserman (1978). The effects of simultaneous versus delayed presentation of choice stimuli have been the focus of these studies. The third procedural variable, the interrelations of the choice and comparison stimuli

both in terms of the number of stimuli involved and their specific stimulus properties, has not been investigated. A fourth procedural variable deserving investigation is whether the matching task is iconic or symbolic. Iconic or identity matching requires the learner to match visually identical symbols, such as a circle to a circle. Symbolic matching requires the learner to match visually dissimilar symbols, such as a lowercase letter to its corresponding uppercase match.

Cumming and Berryman stressed the importance of investigating the numbers of choices in 1963; more recently, this same need has been restated and reinforced by Sidman (1987). The number of choices offered to the learner has continued to vary in matching-to-sample studies and appears contingent on the investigator's decision as to the type of pattern and equipment to be used. Therefore the number of alternative choices is a direct function of the arrangement of the stimuli. Only one study in which a procedural variable related to the interrelationship between sample and choices was systematically manipulated and examined. In this study, two rhesus monkeys learned hue and line discriminations. Iverson, Sidman, and Carrigan (1986) manipulated the position of the sample stimulus in a two-choice linear format across two conditions. In the experimental condition, the sample choice randomly appeared in any of three positions; this randomization determined the subsequent position of the two-choice stimuli. In the control condition, choice stimuli always

appeared in the center key. Learners made choices based on the location of the stimulus. Discriminations that had been learned in the control condition then deteriorated under the experimental condition. The investigators concluded that an accurate description of the controlling choice stimuli should therefore also include spatial location.

The success of matching-to-sample is also dependent on learner involvement during the procedure. Learner activity, which has been standardized as looking and touching behavior, is therefore discussed next. As no studies were located in which numbers of choices were experimentally manipulated in a systematic and direct manner, a descriptive review of major matching-to-sample studies follows. This review contains an historical overview of matching-to-sample and is organized by numbers of choices.

Learner Activity in Matching-to-Sample

As defined by Cumming and Berryman (1963), matching-to-sample is a conditional discrimination procedure in which the learner must first respond to a sample stimulus in order to produce comparison stimuli. This initial response by the learner serves to set the occasion for the presentation of the matching choices. Traditionally, attention to the stimulus has been obtained by direct learner contact with the sample stimulus either by pecking, pointing, or touching. A discussion of the importance of

this initial activity as a situational setup for initiating stimulus presentation and choices follows in terms of the learner first looking and then touching.

Looking as a Feature of Attention

The ability of learners to learn through looking is dependent on both the ability of the learner and the presentation of the stimulus. Learner ability and stimulus content are therefore discussed below.

Learner abilities

Dependent on several skills that are often taken for granted in the learning situation, learners are able to attend to stimuli. These skills include being able to see and process information, to prepare for the presentation of stimuli via preattention skills, or to benefit from specific training that emphasizes the development of preattention or orienting behaviors. A thorough review of this body of literature is beyond the scope of this study; therefore an overview of the major studies is provided.

Visual processing. The visual acquisition and processing system is the human processing system that is most accurate and at the same time most basic to school learning tasks (Getman, 1965). Reaseachers have described infant visual systems that are functionally near adult level at 4 months of age (Clark-Stewart & Koch, 1983). In addition, scanning (Salepatek, 1969; Wollf, 1965), discrimination (Brinker & Lewis, 1982; Fantz, 1966), and choice and matching (Porter, Lahm, Behrmann, & Collins, 1986) skills

have been described among infants and very young children. Learners of preschool age can therefore perceive and process visual information with high degrees of accuracy.

Preattention. Learning is also dependent on the learner's ability to look, listen, and sit quietly during instruction. In the classroom, behaviors such as a particular posture, observing, or orienting towards a stimulus can be indicative of preattending skills. Students who are looking at materials, looking at the teacher when the teacher is modeling materials, listening to oral instruction, or sitting quietly for short periods of time are demonstrating preattending or orienting behaviors (Etzel, LeBlanc, Schilmoeller, & Stella, 1981).

Preattention can also be detected through the careful observation of eye and head movement or other physical symptoms (Lewis, 1972; Neisser, 1967). Stella and Etzel (1986) have suggested that different stimulus manipulations can produce reliable differences in the control of young learner's eye orientations, that orientations might be predictors of pointing, and that there are ways to gain control of visual orientations through the manipulation of antecedent stimulus changes.

Training preattention. Winslow and Etzel (1972) investigated the preattending skills of 80 heterogeneous students who were 4- to 5-years-old. Manipulations of the learning environment were implemented to alter preattending behavior. The type of materials or amount of reinforcement did not affect

inappropriate preattending. Increases in preattending behavior or reductions in inappropriate preattending were not necessarily affected by changes in consequences, easier tasks, or errorless tasks. Rather the training of learner activities such as head and upper body orientation, pointing on demand, and pointing with index finger extended has increased preattending. Children have been taught preattending skills via modeling, prompting, and shaping. For example, one component of such training included a changing-criterion reinforcement schedule that shifted from preattending to task accuracy from the beginning to the end of the training session (Winslow & Etzel, 1972). Others have stated that preattending may not necessarily be related to internal motivation, but rather to the age or disability of the learner. Preattention may therefore be amenable to training (Loper, Hallahan, & Ianna, 1982; Miller & Bigi, 1979).

Stimulus presentation

When considering the ability of the learner to attend, other researchers have emphasized the content or topography of the stimulus (Fleming & Levie, 1978; Vernon, 1952). Cohen and Gross (1979) have identified visual stimuli dimensions (brightness, object movement, patterned and color presentation, external versus internal features, size, number of elements, attention to faces, functionality, and novelty) that follow a developmental sequence. Limitations in the ability to process any of these dimensions may inhibit young learners trying to attend

or focus on an individual stimulus dimension. For this study, the amount of visual information that can be presented to and successfully processed by the learner was considered in terms of the size and organization of the stimuli, as well as the number of learning opportunities. To date, researchers have addressed the number of learning opportunities in terms of the number of problems, the number of trials per problem, and the number of items per trial only.

Size and organization of the stimuli. The size and organization of stimuli are important features in the processing of visual information. Hershenson (1964); and Brennan, Ames, and Moore (1966); as well as Fantz and Fagan (1975) have noted learner preference for smaller elements except when the number of elements has been controlled. Hochberg (1966) and Murch (1973) have suggested that greater accuracy in less time is possible when learners process forms that are simple, regular, closed, continuous, smaller, and symmetrical with uninterrupted, straight lines or smoothly curved contours. The ability to process forms in various organizational patterns has been described as a developmental sequence by Fantz (1966); Fantz and Nevis (1967); and Fantz, Ordy, and Udelf (1973).

In this review of 43 matching-to-sample studies, sample and choice stimuli were incorporated into closed four-sided figures in 35 of the 43 matching-to-sample studies reviewed for this investigation (see Figures 2-1 through 2-9, 2-13, 2-16, and 2-17).

Of this number, 30 patterns were incorporated into horizontal rectangles, 1 pattern into a vertical rectangle (see Figure 2-16), and 5 patterns into a square (see Figures 2-4, 2-7, and 2-17). In 6 studies, stimuli were incorporated into a circle pattern (see Figures 2-10, 2-11, 2-14, 2-15, and 2-18). One study was reviewed in which stimuli were incorporated into a pentagon pattern (see Figure 2-12). In 6 of the 18 organizational choice patterns, circles rather than squares were used for individual stimuli (see Figures 2-10, 2-11, 2-12, 2-14, 2-15, and 2-18).

Berelson and Steiner (1964) have considered learner activity in terms of responding to patterns that are similarly organized and grouped. In the matching-to-sample procedure, learning accuracy and rate, as well as response direction, are directly affected by sample and choice organization (Rettig, 1986a). Response direction is the direction of learner movement from the first orienting response (touching the sample stimulus) toward the response choice. Rettig has stated that learners naturally proceed in a left to right progression and has designed matching-to-sample instructional software to conform to that motion pattern (M. Rettig, personal communication, April 22, 1987). Of 43 matching-to-sample studies reviewed for this investigation, response demands in 16 studies restricted the learner to a left to right motion (see Figures 2-1, 2-6, and 2-7) and in 3 studies, to a downward motion (see Figures 2-2, 2-3, 2-5, 2-8, 2-9, 2-11, 2-13, 2-15, and 2-16). Learner responses in 3

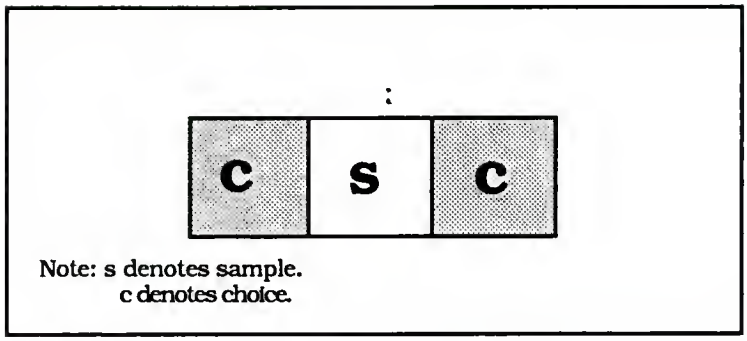

Figure 2-1. Linear two-choice pattern.

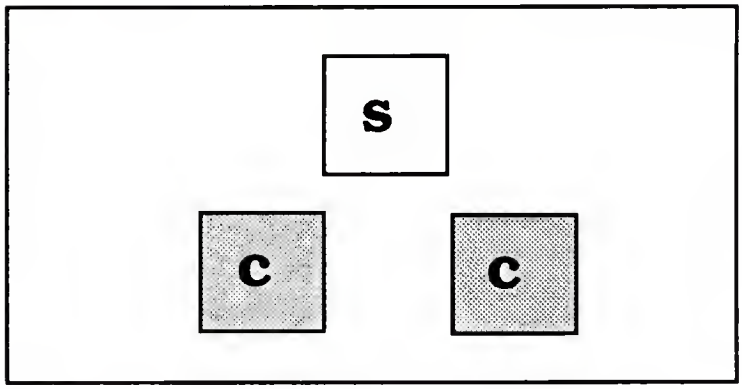

Figure 2-2. Triangular two-choice pattern.

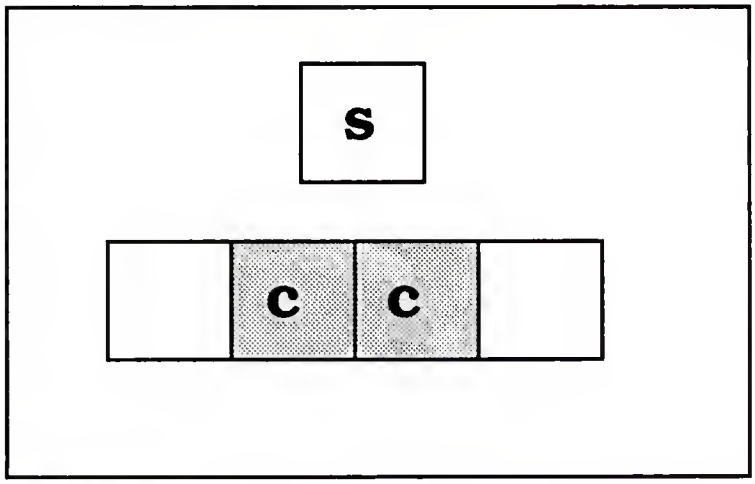

Figure 2-3. Triangular/linear two-choice pattern.

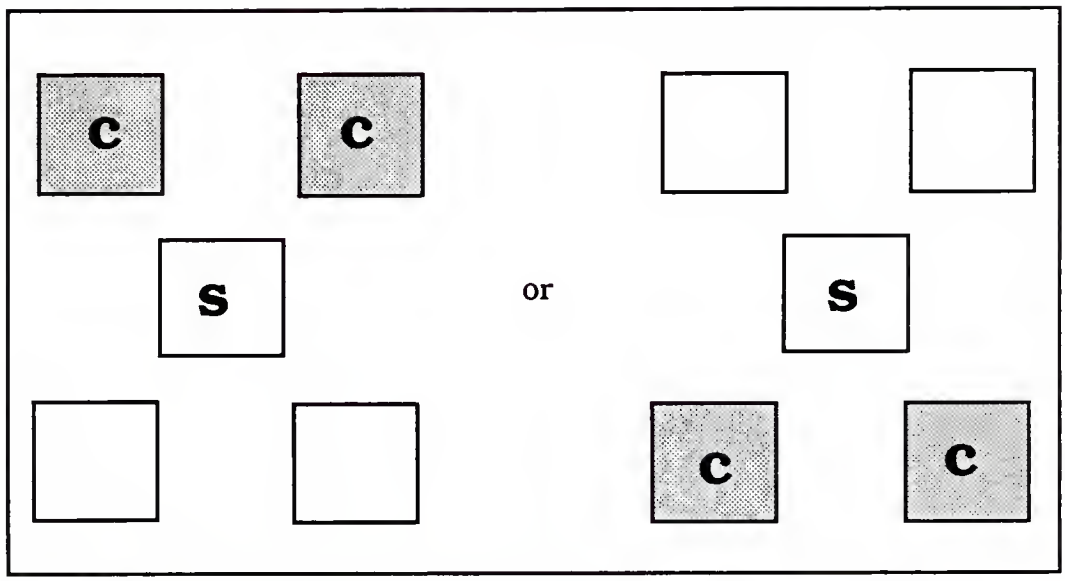

Figure 2-4. Rectangular two-choice pattern.

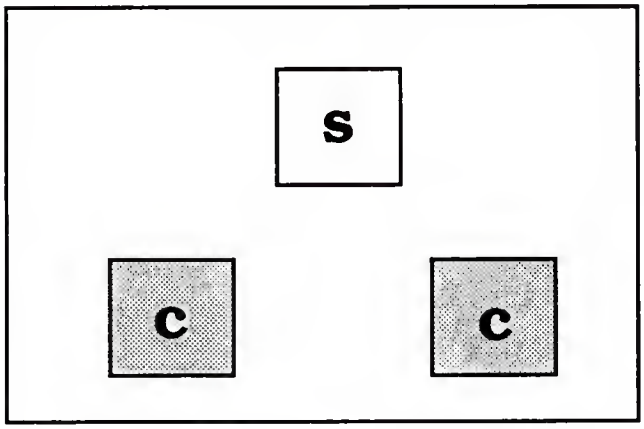

Figure 2-5. Triangular two-choice pattern.

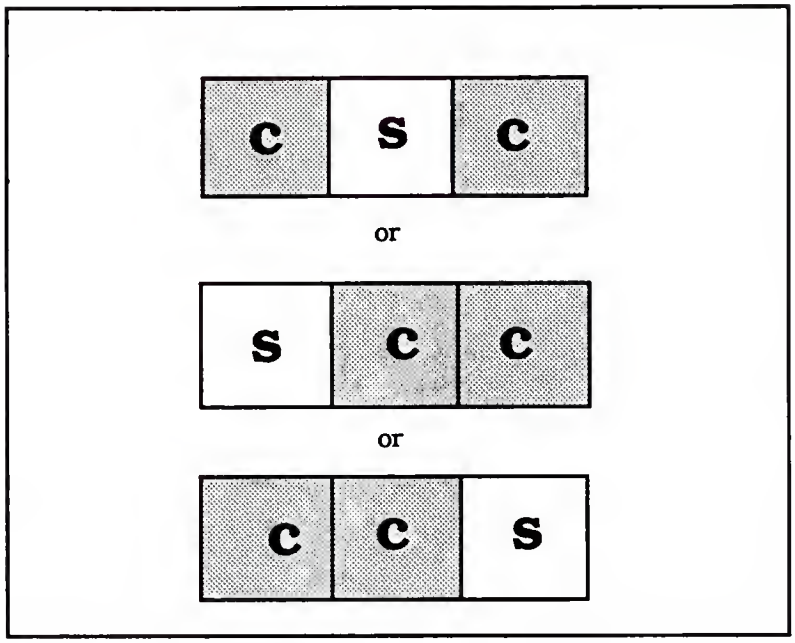

Figure 2-6. Linear/random two-choice pattern.

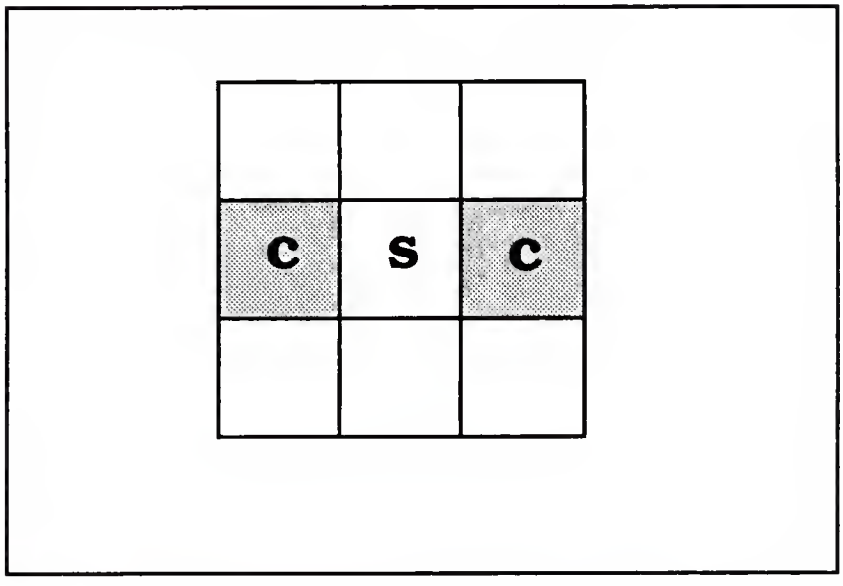

Figure 2-7. Linear/matrix two-choice pattern.

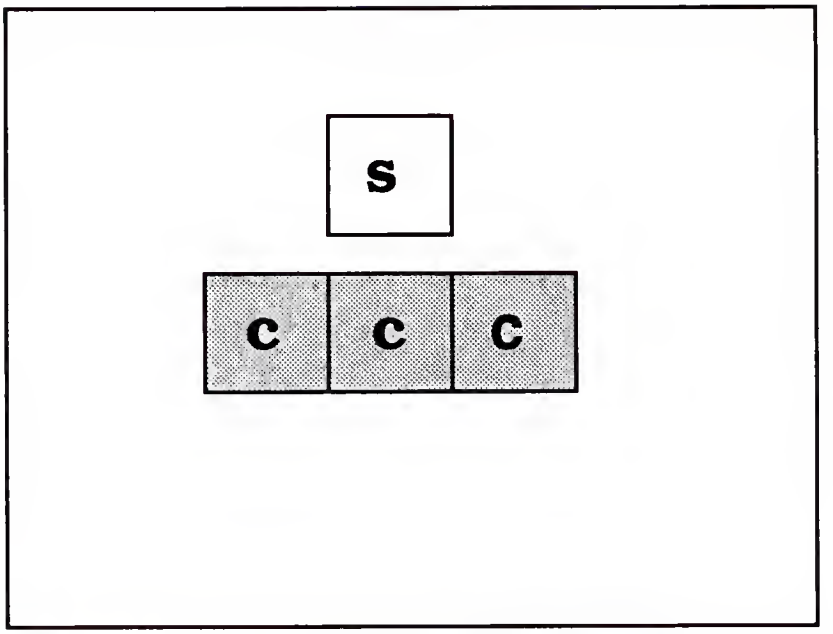

Figure 2-8. Triangular three-choice pattern.

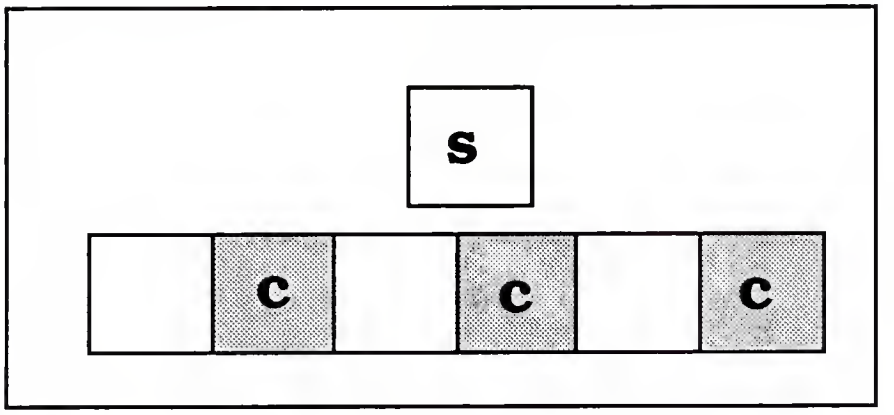

Figure 2-9. Triangular/linear three-choice pattern.

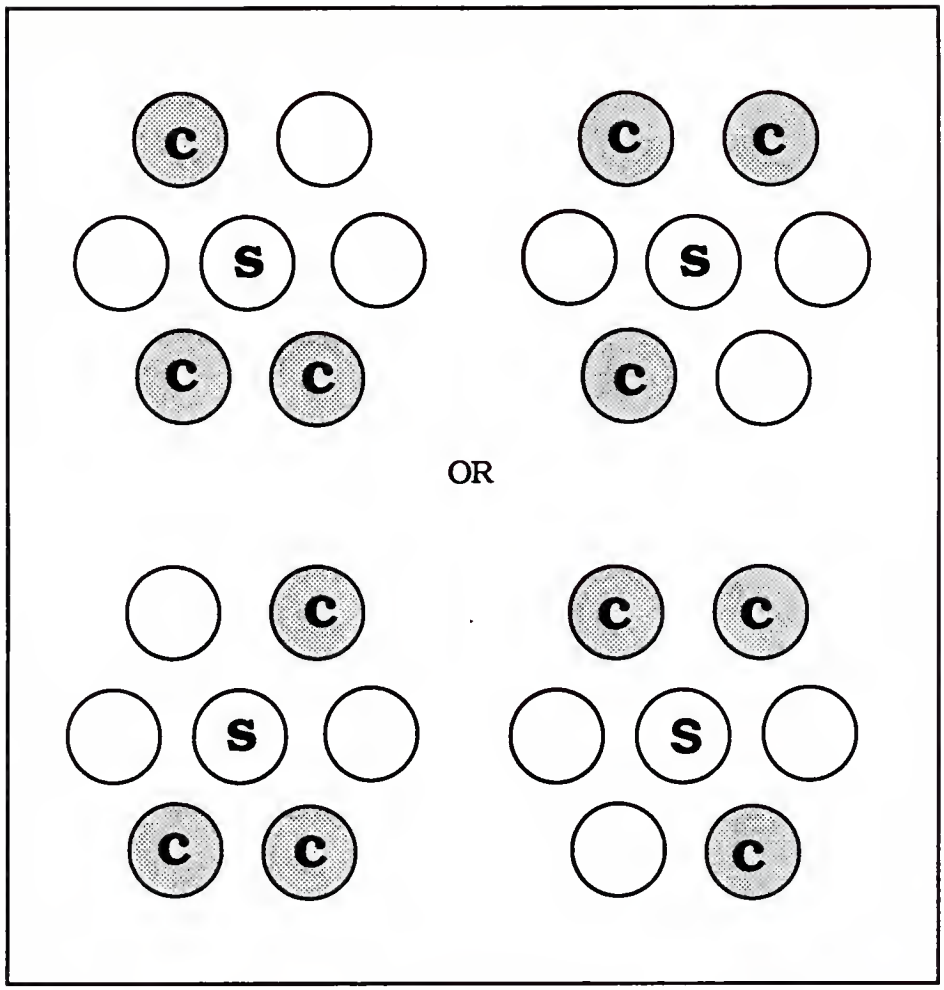

Figure 2-10. Circular/random three-choice pattern.

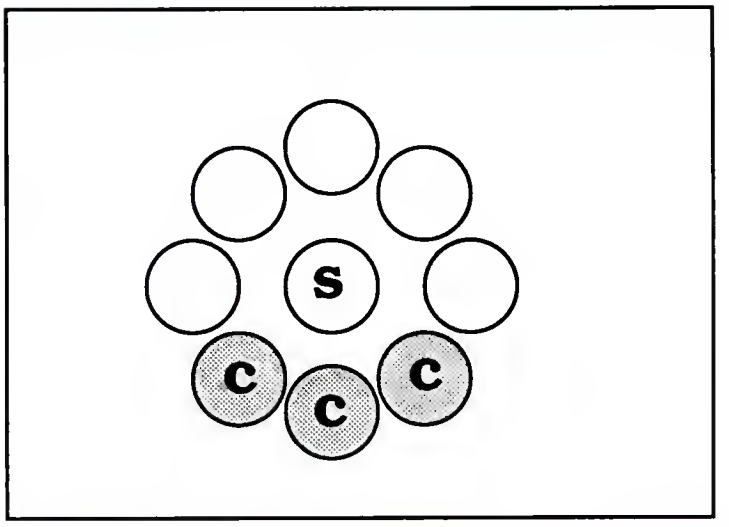

Figure 2-11. Circular/lower three-choice pattern.

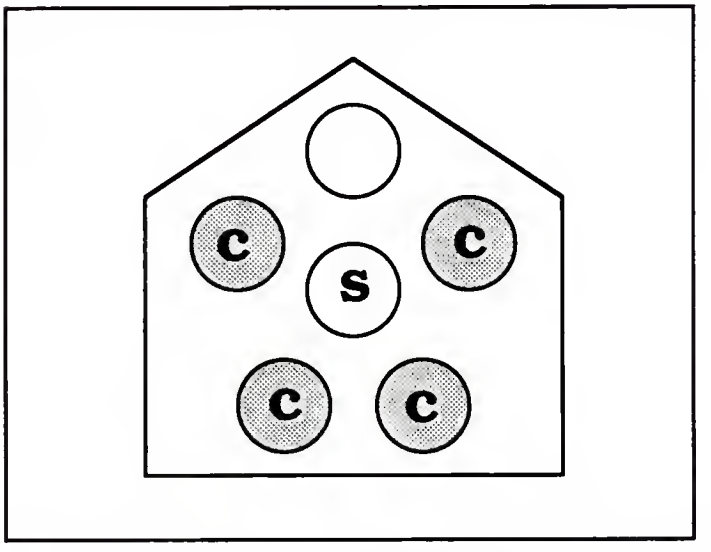

Figure 2-12. Circular/pentagon four-choice pattern (4 choices in any of 5 rim circles).

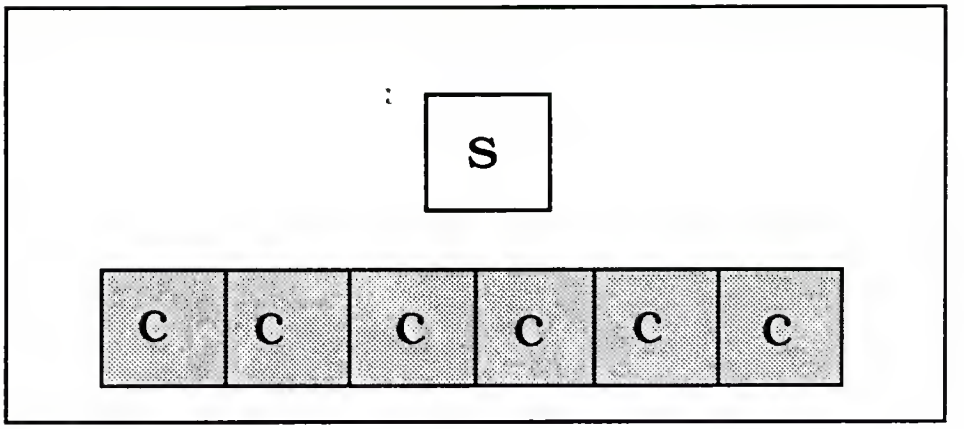

Figure 2-13. Triangular/linear five-choice pattern.

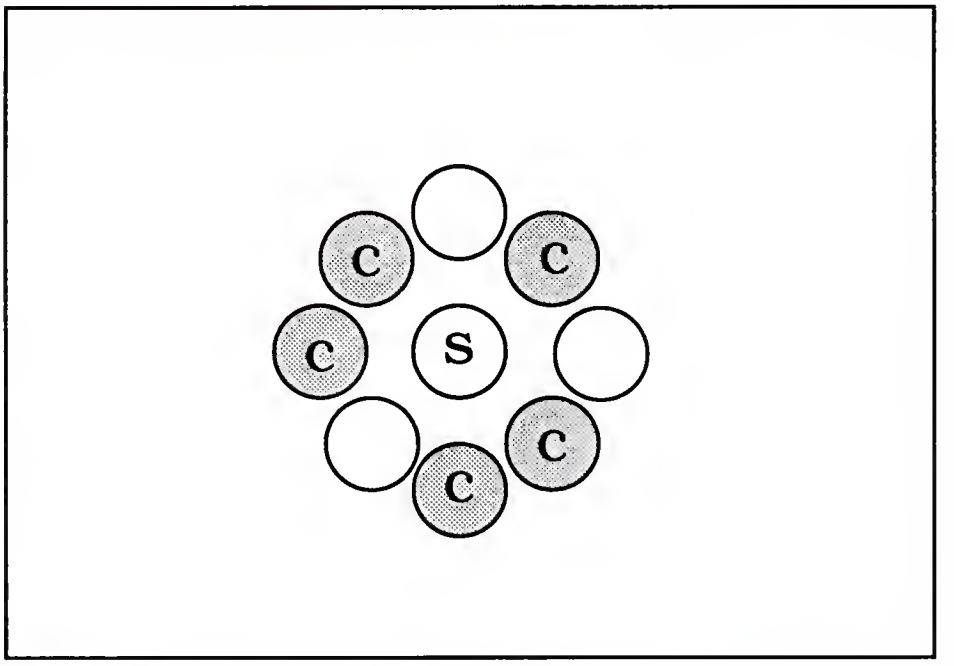

Figure 2-14. Circular five-choice pattern.
(Choices in any of eight locations).

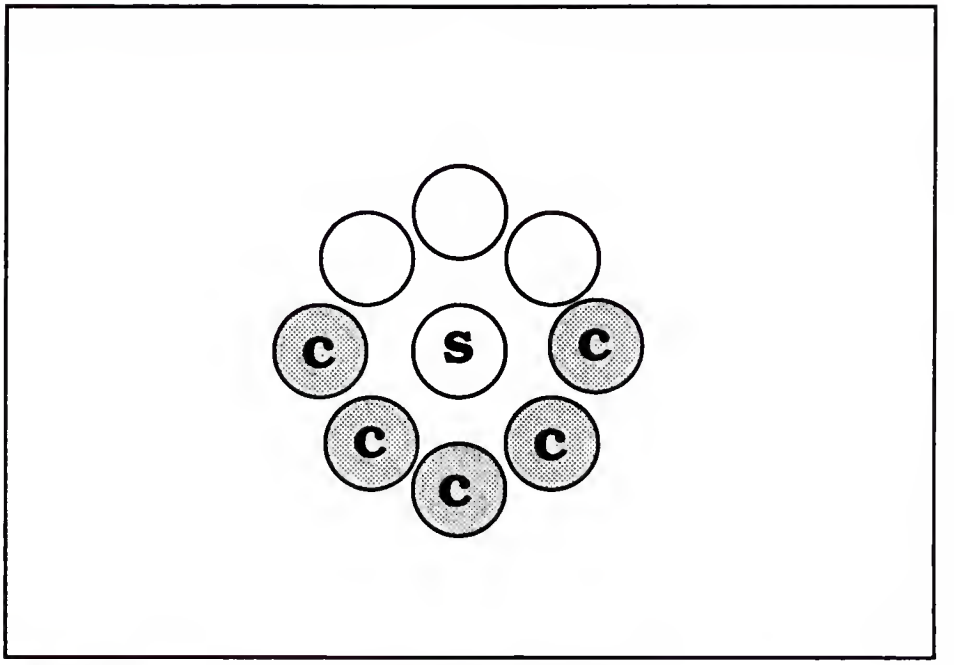

Figure 2-15. Circular five-choice pattern (Choices in five lower locations).

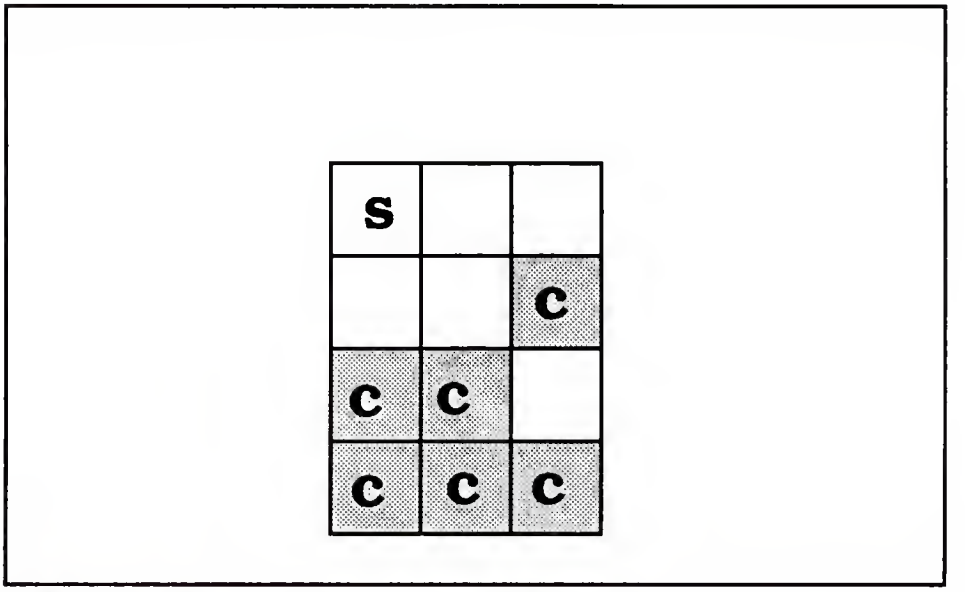

Figure 2-16. Rectangular six-choice pattern (Choices in any of 11 locations).

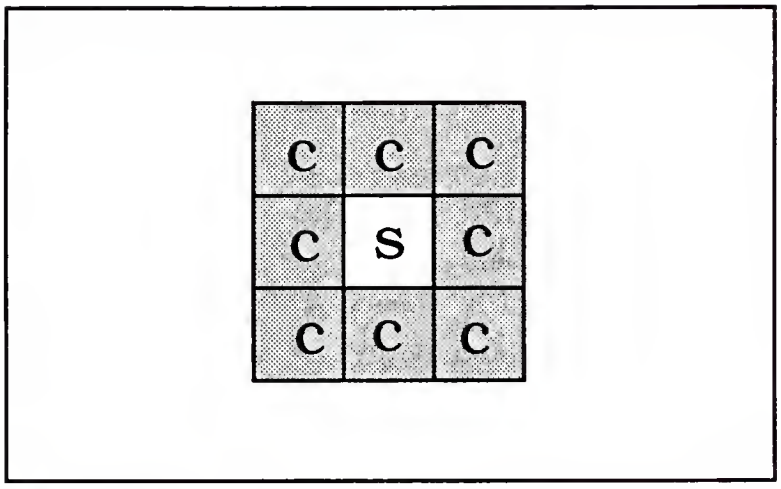

Figure 2-17. Matrix eight-choice pattern.

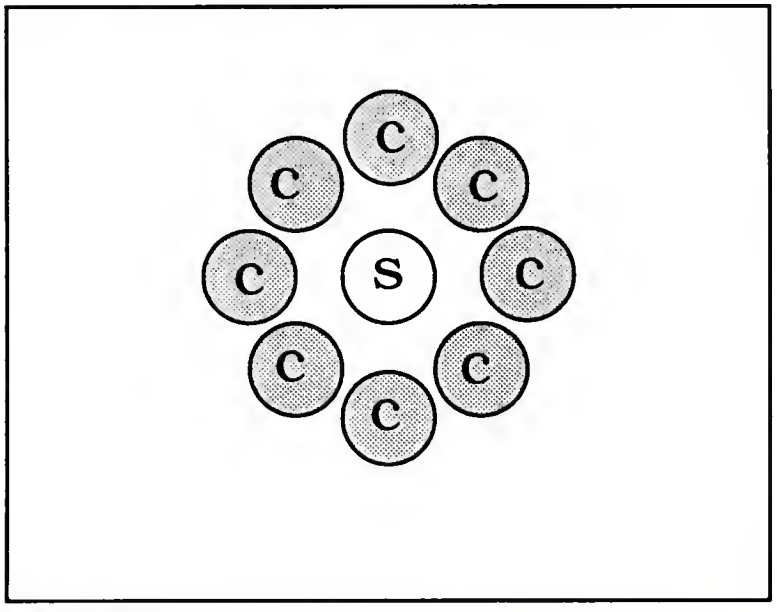

Figure 2-18. Circular eight-choice pattern.

studies were permitted in either upward or downward motion (see Figures 2-4, 2-10, and 2-12); and, in 6 studies, in any direction (see Figures 2-14, 2-17, and 2-18).

Number of learning opportunities. The effect of the number of opportunities to learn has been addressed in various ways. Carnine (1980) advocated large numbers of examples while Harlow (1959) noted that rate, efficiency, and amount of learning were directly related to the number of trials per problem. The smaller number of trials given per problem resulted in a larger number of problems needed to reach criterion. Harlow also correlated the number of trials per problem with stages of learning and the amount learned. Larger number of problems during initial trials (1-100) resulted in more efficient learning as well as greater transfer of skills to successive problems. Hayes, Thompson, and Hayes (1953) corroborated these findings using chimpanzees who, with 2 trials per problem, required 300 trials to learn a new task. With 10 trials per problem, learning occurred more rapidly.

Hershenson, (1964), Brennan et al. (1966), and Fantz and Fagan (1975) have stated that learners prefer large numbers of items. Engelmann and Carnine (1982) have noted that learners are able to work successfully with up to 11 items on a page. In contrast, Miller (1968) has stated that there is a clear and definite limit to the accuracy with which we can interpret and remember stimuli that are presented visually. For unidimensional

judgments, the span of absolute judgment is approximately 7 units. The commonality of the number seven has been noted across a wide range of disciplines, stimuli, and modalities (Miller, 1968). Chunking or clustering individual units of information can result in increased capacity for remembering; yet the numbers of items on a page in relation to the encoding process can limit other information processing.

Consideration of the units of size, number, as well as organization contribute to the presentation of stimuli in a manner that can facilitate learning. This consideration, in combination with the ability of the learner, sets the occasion for the learner to respond and produce the discriminative stimulus in the matching-to-sample procedure.

Touching as an Active Learner Response

Often, to facilitate the preattention of the learner, topographical cues such highlighting, arrows, color, sound, and movement are incorporated into the stimulus presentation. As an alternative to this external control, Lewis (1972) has referred to responses by the learner that facilitate the reception of stimuli and help direct action to those stimuli.

Touching in matching-to-sample

In discriminative learning experiments, learners have been required to take some action such as pressing a response key prior to being exposed to the discriminative stimulus (Ferster, 1960; Sidman, 1971). Wyckoff (1959) showed that pigeons

demonstrated increased key pressing (mediating response) to produce a color change when that color change was reinforced under a fixed interval (FI) 30-second reinforcement schedule. Kelleher (1958) used monkeys to illustrate discriminative learning with a similar task that required a mediating response to produce a discriminative stimulus. Lindsley (1962) noted that the operant response of pushing a button at 60 presses per minute to maintain audio or visual intensity eventually became equated with a response that resembled looking, such as bending or turning the head. Findings have been expanded further to include responses to both looking and listening tasks presented in schedules designed according to the individual learner's baseline performance. The act of pointing or reaching orients the learner toward the presentation of the sample stimulus in the matching-to-sample procedure. Pointing can also provide an accurate measurement of active learner responding and has been correlated with increases in achievement (Greenwood, Delquadri, & Hall, 1984).

Touching with young learners and microcomputers

Rettig (1986a) has insisted that touch is the only logical response mechanism for learners of preschool age or for those with young mental ages. This response option has been facilitated further by the introduction of the microcomputer into the classroom. The ability to scan the contents of a computer screen is identical to the ability of very young infants to make visual

choices and determine preferences as described above. The microcomputer can provide a tool for examining the learning of infants and handicapped learners (Brinker, 1984). While Porter et al. (1986) have stated that learners as young as 15 months can use the computer as a functional tool, Brinkley and Watson (1986) have suggested 3 years of age as optimum for the successful introduction to the microcomputer as a learning tool. Rettig (1987) has corroborated this view by stating that the years from 2 to 5 are appropriate for introducing the microcomputer to the young learner.

The existence of large numbers of microcomputers in classrooms also requires that software developers become aware of the developmental age and abilities of the intended users in order to identify appropriate software content, as well as presentation and response modes (Johnson, 1986). Rettig (1986b) has stated that inaccurate measurement of a learner's ability may increase when inappropriate computer response modes are used. When determining the appropriate response mode, one should consider that the learner should be able to respond without taking time to think about <u>how</u> to respond. Rettig (1986b) investigated alternate response modes on the microcomputer with young mentally retarded and physically handicapped children to determine possible differences in response frequency or accuracy. The color matching skills of 20 physically impaired and 20 mentally retarded children from 3 to 6

years of age were compared using four different response modes (keyboard, keyboard adaptation, paddles, and light pen) on a microcomputer. Keyboard responding was highest in frequency and lowest in accuracy. The paddles response mode generated the highest improvement in accuracy over time. Because of the distraction factor (focus on the keyboard and not on the stimuli), the keyboard response mode was determined to be the least appropriate for young learners.

Rettig (1986b) has stated further that almost any adaptation in response mode can improve the accuracy of young learners when using the microcomputer and has targeted the touchscreen as the most appropriate response mechanism for preschool students and learners with young mental ages. With a touchscreen, learners touch directly on the screen; attention is therefore focused on the screen and this interactivity increases learner involvement. Responses can be fast, easy, direct, natural, and more appropriate than other response modes such as paddles, keyboards, or joysticks (Serna, 1987). Touchscreen and microcomputer technology offer effective, efficient, appropriate, and reliable means by which to investigate the effect of the numbers of choices in a matching-to-sample procedure with young learners.

Number of Matching-to-Sample Choices

The number of choices offered the learner in matching-to-sample tasks has continued to vary. In recent years, new technologies have been developed to implement matching-to-sample.

sample. Electronic equipment has facilitated the delivery of more sophisticated patterns that have subsequently determined the number of choices offered to the learner. Investigators have appeared to change the number of choices based on findings related to other experimental variables or the need to save experimental time (Sidman, 1987). These changes have occurred not only from experiment to experiment (Sidman, 1987) but also within the same experiment (Sidman & Cresson, 1973; Sidman, et al., 1974).

A review of the historical development of the matching-to-sample procedure resulted in the location of 43 major studies in which the number of choices and pattern arrangement were clearly described. Only one study was found in which a procedural variable that indirectly affected the number of response choices was systematically manipulated (Iverson et al., 1986). No studies in which the number of choices in a matching-to-sample procedure was directly and systematically varied were located. In order to provide a review of important, well-designed, and completely reported matching-to-sample studies, these investigations have been organized into categories that reflect the numbers of response choices. Two-, three-, four-, five-, six-, and eight-choice studies are presented in Tables 2-1 through 2-6. These studies will be discussed according to the numbers of choices, primarily in terms of pattern arrangement, types of learners, and learner tasks. As the number of choices has never

been the manipulated variable in a matching-to-sample study, only those findings of major significance for matching-to-sample technology or those indirectly related to a subsequent change in the number of choices will be discussed.

Two-Choice Matching-to-Sample Studies

Matching-to-sample tasks in which a two-choice format (see Table 2-1) was used originated from attempts to extend simple yes-no conditional discrimination tasks that had been used successfully in the laboratory. Terrace (1963a, 1963b) taught pigeons to discriminate without making any "errors" and then transfer this control to other stimuli. Sidman and Stoddard (1966) demonstrated the effects of subtle discrimination programming on the ability of a severely retarded adult to discriminate circular forms. Nine translucent panels were arranged in a three by three matrix onto which circles or ellipses were projected. Through instruction and reinforcement, the subject learned first to touch the panel and then to discriminate circles from ellipses. Electronic control of stimulus presentation and reinforcement provided the tools with which to implement these studies.

Two-choice matching-to-sample equipment

Catania (1979) has described a three-key pigeon chamber in which the sample stimulus was located in the center and

Table 2-1

Summary of Two-Choice Matching-to-Sample Studies

Author/s	Learner/s Activity	Pattern Arrangement[a]	Equipment	Dependent Variable/s Results
Skinner 1950	Pigeons See/peck	Linear s: center c: left/right	Three-key pigeon chamber	Number of correct pecks Higher probability of errors in trials immediately following intermittent reinforcement
Ferster 1960	2 white Carneau pigeons 6-20 months See/peck colors	Linear s: center c: left/right	Three-key pigeon chamber	Number of correct pecks Demonstrated matching with variable interval and fixed-ratio reinforcement

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Cumming & Berryman 1961	Pigeons See/peck colors	Linear: s: center c: left/right	Three-key pigeon chamber Lights Reinforcement magazine	Number of correct pecks Large numbers related to Harlow's learning set theory Position habits developed Rapid latency
Cumming & Berryman 1965	Pigeons See/peck	Linear: s: center c: left/right	Three-key pigeon chamber	Number of correct pecks Higher probability of errors immediately following reinforcement Matching accuracy may be related to latency of response

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Nevin, Cumming, & Berryman 1963	7 Pigeons See/press	Linear s: center c: left/right	Three-key pigeon chamber	Number of correct presses Higher probability of errors on trials immediately following reinforcement (fixed-ratio schedule) Accuracy related to latency of responses Chains of behavior
Verhave 1966	Pigeon See/peck pills	Triangular s: above c: below	Assembly line Touch sensitive keys Pellet Dispenser	Number of correct pecks Matched pills to standard Made yes/no peck

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Nevin 1967	Pigeons See/peck	Linear s: center c: left/right	Three-key pigeon chamber	Number of correct pecks "Passed" when given option Otherwise most often correct (discrete trials, simutansous discrimination Matching accuracy related to latency of response and longer time to view sample
Over & Over 1967	Normal preshcool 8 male 8 female CA: 4-0 to 6-5 years See/Touch mirror images	Triangular s: above c: below	Plaques on table surface	Number of correct touches Recognition (two-choice discrimination) task resulted in fewer errors than detection (matching-to-sample

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Wohlwill & Hall 1968	24 children CA: 47-56 months See/touch figures	Triangular s: above c: below	Frame Cards Red light Electric timer	Number of correct touches Figures with vertical reversal factors resulted in fewer errors than figures with horizontal reversal factors.
Eckerman 1970	Pigeons See/peck lines and colors	Linear s: center c: left/right	Three-key pigeon chamber	Number/percent of correct matches Symbolic matches

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Wright & Cumming 1971	6 pigeons See/peck light waves	Linear s: center c: left/right	Three-key pigeon chamber Three light sources	Number/percent of correct pecks Determined transition points between hues for pigeons Spectrum may differ for humans
Maki & Levin 1972	2 pigeons See/peck colored lights	Linear s: center c: left/right	Three-key pigeon chamber Sound-attenuated chamber Computerized presentation	Number of correct pecks Attention divided into critical components as determinants of performance

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Spradlin, Cotter, & Baxley 1973	3 mentally retarded adolescents See/press shapes	Triangular s: above c: below center (2/4)	Four-choice apparatus 35 mm. slides Rear screen projector Microswitches Bell Buzzer	Number of correct presses Derived matching relations via comparison of 2 comparison sets to complementary sample (ac, bc, ad => bd)
Thomas 1973	Pigeons See/peck	Linear s: center c: left/right	Three-key pigeon chamber White noise Rear projector House light	Number of correct pecks Intertrial interval affects accurary

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Farthing & Opuda 1974	8 pigeons See/peck colors and forms	Linear s: center c: left/right	Three-key pigeon chamber	Number of correct pecks Learning as a set of specific stimulus-response chains Extra pecks on center key orienting behavior Overt cues produced Response increases during acquisition
Carter & Eckerman 1975	20 pigeons See/peck lines colored lights	Linear s: center c: left/right	Three-key pigeon chamber	Number of correct matches Symbolic matching learned quickly and may be dependent on stimulus dimensions

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Dixon & Spradlin 1976	4 male 3 female mentally retarded adolescents See/touch pictures	Triangular s: above center c: below	Stimulus display box Reinforcement delivery system Carousel slide projector Chimes/Buzzer Tape Recorder Feeder system Programmed delivery	Number of correct touches Development of untrained performances with natural language stimulus in laboratory
Spradlin & Dixon 1976	2 mentally retarded adolescents CA: 13 & 17 years See/touch Hear/touch	Triangular s: above center c: below	Stimulus display box Reinforcement delivery system Carousel slide projector Chimes/Buzzer Tape recorder Feeder system Programmed delivery	Number of trials to criterion Visual to visual matching Development of untrained performances with natural language stimulus Auditory to visual matching required specific training - label for one member of class did not necessarily translate to another.

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Nelson & Wasserman 1978	4 pigeons See/peck	Linear s: center c: left/right	Three-key pigeon chamber	Number of correct pecks Accuracy related to duration of sample presentation and latency of response
Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan 1982	Rhesus monkeys Baboons Normal children CA 4-6 years See/touch symbols	Rectangle s: center c: in 2 of 4 corners	Monkey test chamber In-line projectors with response mechanisms Pellet dispensers Lights Punched-tape reader Elecxtro-mechanical and electronic recorders 20-pen event recorder	Number of correct presses With nonhumans: No matching-to-sample as evidence of backward associations or associative symmetry Transitivity asbsent in conditional discriminations. Unclear whether results related to experiential or genetic variables

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Stromer & Osborne 1982	12 mentally retarded adolescents See/touch	Triangular s: above c: below	Rear projector Chimes/buzzer Feeder Digital Counter Response Panel Token dispenser	Number of correct matches Replicated arbitrary matching and formation of equivalence classes Reversibility Visual to visual training with previously-known choices
Wetherby, Karlan, & Spradlin 1983	4 male 4 female CA 4-9 to 5-6 years See/press	Triangular s: above c: below 2/4	Electro-mechanical equipment in stimulus display cabinet Carousel projector Token feeder Chimes/buzzer	Number of correct presses Visual to visual training Replicated findings of substitutability as prime determinant of derived stimulus relations

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
D'Amato, Salmon, Loukas, & Tomie 1985	Monkeys Pigeons See/press	Triangular s: center c: above	Response keys on 5 in-line projectors (only 3 used)	Number of correct presses Differences in interspecies performance with regard to symmetry and transitivity - monkeys and pigeons did not make backward associations.
Devaney, Hayes, & Nelson 1986	12 Children MA: 12-36 months 4 normal 4 mentally retarded 4 language impaired See/touch symbols	Triangular s: center c: bottom (far left/ right)	Sheets of paper held horizontally	Number of correct matches Subjects with normal language developed stimulus classes

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Iverson, Sidman, & Carrigan 1986	2 Rhesus monkeys See/touch hues and lines	Linear s: any of 3 positions c: any of other 2 positions	Chamber Pellet dispenser IEE projector House light Computer controlled sequences 20-pen event recorder	Number of correct presses Conditional Line discriminatiuon based on stimulus line discrimination
Spradlin & Saunders 1986	Normal retarded & language-impaired children & adolescents See/touch shapes	Linear within matrix s: center c: left/right	Stimulus display box Electronically senstitive touch response panels Tray feeder Digital counter Audio-Cassette tape drive Digital printer Programmed presentation	Number of correct touches Matching single comparison to four samples resulted in stimulus class formation; Matching multiple stimuli to a sample did not result in stimulus class formation.

Table 2-1--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Stromer 1986	8 mildly mentally retarded adolescents See/touch novel vs. familiar	Triangular s: upper center c: bottom	12 Stimulus in-line projectors Touch sensitive switches Token Feeder Digital Counter Printout Chimes/Buzzer Tape reader	Number of correct matches Choices made due to control by exclusion
Serna 1987	Adults See/move & press at symbol	Triangular s: above c: below	Apple IIe computer Joystick Two computer monitors Disk drives Printer Applesoft BASIC Paddle Graphics	Number of correct moves Results obtained with minimal equipment and joystick - less fatigue Greater manipulation of procedural variables (intertrial interval, feedback and reinforcement)

Note. Tables categorized by numbers of choices and sequenced by year and author.
a. "s" denotes sample; "c" denotes choice

comparison stimuli on the left and right of the sample stimulus (see Figure 2-1). Pecking on the center key ensured looking and also illuminated the two side (choice) keys. Pecking on the matching choice key produced a reinforcer, followed by the presentation of a new sample and two new comparison or choice stimuli. A nonmatching side-key peck could be followed directly by the presentation of a new stimulus without a reinforcer or an intertrial interval without a reinforcer. Sample stimuli were varied from trial to trial as was the position of the matching choice. These chambers were operated electronically and were used in the early studies by Skinner (1950); Ferster (1960); Cumming and Berryman (1961); Nevin, Cumming, and Berryman (1963); Nevin (1967); Wright and Cumming (1971); Maki and Levin (1972); Carter and Eckerman (1975); Thomas (1973); Farthing and Opuda (1974); and Nelson and Wasserman (1978). The success of the procedure with pigeons was also demonstrated by Verhave (1966) in a slightly different format (see Figure 2-2) in which pigeons matched pills to a standard as a measure of quality control.

The equipment used in two-choice studies has evolved from the simple three-key pigeon chamber to sophisticated electronic equipment that can deliver stimuli consistently and record behavior reliably. Reinforcement devices have been modified from pellet dispensers (Verhave, 1966) to bells, chimes, and buzzers

(Spradlin et al., 1973). Other modifications have included sound-attenuated chambers (Maki & Levin, 1972); white noise (Thomas, 1973); tape-recorded presentation (Spradlin & Dixon, 1976); electronically operated microswitches sensitive to the touch; computerized presentation of stimuli (Maki & Levin, 1972); punched-tape readers (Sidman et al., 1982); electro-mechanical, electronic 20-pen event recorders (Sidman et al., 1982); digital counters (Stromer & Osborne, 1982); carousel slide projectors (Wetherby, Karlin, & Spradlin, 1983); and computer and monitors that have incorporated joysticks, keyboards, modified keyboards, paddles, and touchscreens (Rettig, 1987; Serna, 1987).

Two-choice matching-to-sample pattern organization

Changes in equipment provided the opportunity to alter the organizational patterns of stimuli. Choice stimuli could be presented either above the response choices (see Figures 2-2, 2-3, 2-4, and 2-5), below the response choices (see Figures 2-4 and 2-8), or within a matrix that totally surrounded the sample stimulus (see Figure 2-7). The opportunity for moving stimuli to different positions also provided the means for additional areas in which no response choices were given (see Figure 2-3, 2-4, and 2-7). Finally, overall patterns within which stimuli were organized changed from the linear three-key pigeon format to an overall triangular (see Figures 2-2, 2-3, and 2-5), rectangular (see Figure 2-4), and square format (see Figure 2-7).

Two-choice matching-to-sample findings

Laboratory experiments (often with other numbers of choices) with retarded, nonreading adolescents resulted in the development of performances that had not been specifically trained. After matching pictures to words, learners were able to read words (Sidman, 1971). These findings of untrained performances (stimulus equivalence) led to subsequent studies in which the modality of stimulus presentation and ultimate learner responses (Dixon & Spradlin, 1976; Joyce & Wolking, in press) were addressed. Spradlin and Dixon (1976) demonstrated the effectiveness of visual to visual (intramodal) matching while Sidman and Cresson (1973) demonstrated the effectiveness of auditory to visual training. These findings were later substantiated by Wetherby et al. (1983). Attempts have been made to investigate intraspecies (Wright & Cumming, 1971) as well as interspecies differences. Researchers have sought to determine whether nonhumans (monkeys and baboons) are truly able to achieve stimulus equivalence (D'Amato, Salmon, Loukas, & Tomie, 1985). Sidman et al. (1982) have attempted to determine if differences exist in animal and human performance through tests of transitivity, symmetry, and reflexivity. It remains unclear as to whether the emergence of untrained matching-to-sample tasks is limited to humans or may be possible in other primates.

In other studies in which two-response choices were made available to the learner, researchers have investigated reinforcement schedules. Both human and nonhuman learners have been exposed to schedules of intermittent reinforcement (Skinner, 1950) and schedules of variable, interval, and fixed-ratio reinforcement (Ferster, 1960; Nevin et al., 1963).

In some studies, findings regarding matching-to-sample procedures have simply been noted, without manipulation of these procedural variables within the context of the study. Cumming and Berryman (1961) reaffirmed Sidman and Stoddard's (1967) earlier findings that learners tend to develop position habits and respond to the same key if sample stimulus presentation is not randomized. Nevin (1967) noted that response latency appeared to decrease when subjects were given larger amounts of time to observe the sample; Makin and Levin (1972) related response latency to the length of the intertrial interval or the complexity of the stimuli. Rapid response and learning have been substantiated by Cumming and Berryman (1961) and Sidman and Stoddard (1966) who have described learning within a period of 5 minutes with a severely retarded subject. Cumming and Berryman (1961) also noted that the large number of correct responses appeared related to Harlow's learning set theory in which high accuracy is correlated with many practice opportunities (Harlow, 1959).

Although several investigators (Serna, 1987; Sidman, 1987) have suggested that greater attention be paid to the manipulation and subsequent effect of procedural variables such as intertrial interval, feedback, reinforcement, and numbers of choices, only one study was located in which a procedural variable related to numbers of choices was manipulated. Iverson et al. (1986) found that learner accuracy was directly related to the consistent position of the sample and therefore the choice stimuli. Iverson et al. (1986) have suggested that failure to specify stimulus location may generate unwarranted conclusions regarding performance and that findings by Cumming and Berryman (1965),Farthing and Opuda (1974), and Sidman et al. (1982) may have been confounded by the position or number of choices in the matching-to-sample procedure.

Three-Choice Matching-to-Sample Studies

Matching-to-sample studies in which three-response choices have been incorporated into the procedures (see Table 2-2) were based on teaching machines developed by Skinner (1968) who modified the earlier testing machines of Pressey (1926). Subsequent interpretations of the teaching machine used nonmechanical, mechanical, and electronic devices.

Three-choice matching-to-sample equipment

Teaching machines were devised to provide necessary and precise arrangements of contingencies of reinforcement to bring behavior under the control of specific classes of stimuli. Skinner

Table 2-2

Summary of Three-Choice Matching-to-Sample Studies

Author/s	Learner/s Activity	Pattern Arrangement[a]	Equipment	Dependent Variable/s Results
Skinner 1968	College students See/touch	Triangular s: above c: below	Teaching machine	Trials to criterion Effective instruction of freshman-level college course
Lahey & McNees 1975	2 groups of 15 preschool students See/circle upper and lowercase letters	Linear s: above c: 6 below	3 x 5 cards Transfer letters Screen Poker chips Human recorders	Number of correct and error matches Large individual differences in accuracy of letter discriminations Effectiveness of operant techniques

Table 2-2--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Lazar, Davis-Lang, & Sanchez 1984	Normal learners 3 male 1 female CA 5-3 to 7-2 years See/touch	Circular s: center c: rim of 6 only top and bottom 2 used	Paper tape reader Modern teaching machine Continuous fanfold paper Electronic "windows" Solid-state controls Tape recorder Token dispenser Liquid crystal shutters	Number of correct matches Visual to visual matching without naming Expansion of equivalence classes
Sidman, Kirk, & Willson- Morris 1985	5 normal children 1 retarded adult See/touch Hear/touch words	Circular s: center c: edges (only lower 3 of 8 used)	Slide carousel projector Chimes Token dispenser Nova minicomputer Program procedures Pen/human recorder Tape loop	Number of correct matches Emergence of 60 untrained conditional relations via combining of three 6-member classes

Table 2-2--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Sidman, Willson-Morris, & Kirk 1986	2 normal children CA 5 years 4 retarded adults See/touch symbols	Circular s: center c: rim of 8 only lower 3 of 8 used	Carousel slide projector Solid-state computerized programming equipment Impulse counters 20-pen operations counter Tape loop system Computer	Number of correct matches Naming not necessary for formation of equivalence classes Correlation between numbers of classes formed and developmental retardation

Note. Tables categorized by numbers of choices and sequenced by year and author.
a. "s" denotes sample; "c" denotes choice

believed that subtle discriminations could be learned and that such behavior could be maintained in strength for long periods of time. It was hoped that this type of teaching might make it possible to translate the successes of the operant conditioning laboratory into opportunities for any learner.

Skinner (1968) noted many advantages of the teaching machine. These advantages included immediate reinforcement, individualized presentation and modifications, eventual errorless learning, the incorporation of supplemental reinforcers, alternative uses of teacher time, sequenced instruction, and automatic recording of learner performance. Skinner viewed young children as disadvantaged if such tools were not present in their learning environment.

Other investigators have used three-choices format (see Figures 2-9, 2-10, and 2-11). Lahey and McNees (1975) used three choices in a traditional format, but with a slightly altered teaching format (see Figure 2-9). While some investigators have used 3 by 5 inch cards and human recorders to teach letter discriminations to preschoolers (Lahey & McNees, 1975), others have used electronic equipment when working with both normal and retarded children and adults (Lazar, Davis-Lang, & Sanchez, 1984; Sidman et al., 1985; Sidman, Willson-Morris, & Kirk, 1986). This equipment included carousel slide projectors, solid-state computerized programming equipment, impulse counters, a tape loop system, and token dispensers with which these

investigators could modify the format of the sample and choice stimuli.

Three-choice matching-to-sample pattern organization

Teaching machines were designed in many instructional formats, one of which was matching-to-sample. A standard model used three response choices below the sample stimulus (see Figure 2-8). Skinner (1968) used this format to teach part of a course in human behavior to undergraduate college students.

Sidman et al. (1985, 1986) used an eight-circle arrangement in which only the bottom three circles contained response options. Lazar et al. (1984) used a six-circle arrangement in which any of the top or bottom circles might have contained the three response options. Findings from studies by Sidman et al. (1985, 1986) and Lazar et al. (1984) supported and extended previous findings with regard to the emergence of untrained learning and expansion of stimulus classes.

Four-Choice Matching-to-Sample Studies

Saunders and Sherman (1986) have conducted the only study reported in this review in which a four-choice procedure was utilized (see Table 2-3). Their instructional device was constructed from a white plexiglas panel that was mounted on a plywood wall. Five holes were cut in a rough circle for responses; stimuli were projected onto four of the five openings from the rear and illuminated with 60-watt light bulbs (see Figure 2-12). Reinforcement was delivered via a marble dispenser. Each

Table 2-3
Summary of Four-Choice Matching-to-Sample Studies

Author/s	Learner/s Activity	Pattern Arrangement[a]	Equipment	Dependent Variable/s Results
Saunders & Sherman 1986	Mentally retarded adolescents 2 male 1 female See/touch	Pentagon s: center c: 4 in "circular" rim	While plexiglass panel mounted on plywood wall with 5 holes in rough circle Rear projector 60 watt light bulbs Marble dispenser	Number of correct touches Intertrial interval length may be important variable in matching-to-sample and choice behavior. Choice procedures can produce differential responding to reinfroced and unreinforced samples Strong position bias

Note. Tables categorized by numbers of choices and sequenced by year and author.
a. 's' denotes sample; 'c' denotes choice

sample stimulus was centered within the response option. This study was conducted with two male and one female mentally retarded adolescents and intertrial interval length was identified as a potentially important variable in matching-to-sample and choice behavior. Position bias, wherein the learner appears to make choices based upon the location of the response key, was noted and reaffirmed the previous findings of Cumming and Berryman (1961) and Sidman and Stoddard (1967).

Five-Choice Matching-to-Sample Studies

The three five-choice matching-to-sample studies located for this review used electronic equipment similar to that used in previous studies (Sidman et al., 1982, 1985, 1986) and these studies are summarized in Table 2-4. Tawney (1972) conducted a group study with 13 males and 7 females of preschool age in which a more typical triangular/linear formation was used (see Figure 2-13). Sidman and Tailby (1982) confirmed the emergence of multiple numbers of stimulus relations without directly training a common sample or choice. A circular format was used in which only the lower five circles (out of a possible eight) were used (see Figure 2-15).

Sidman et al. (1974) conducted two separate experiments. In each, subjects were required to see/touch a picture and then see/touch its corresponding word. One subject completed the experiment with a five-choice condition (see Figure 2-14) and the other with an eight-choice condition (see Figure 2-18). Both

Table 2-4

Summary of Five-Choice Matching-to-Sample Studies

Author/s	Learner/s Activity	Pattern Arrangement[a]	Equipment	Dependent Variable/s Results
Tawney 1972	13 males 7 females CA 4 years 2 groups See/touch Expermental group reinforced according to critical measures	Triangular s: above c: below	Slide projector Microswitch response Red light Chimes Dispenser	Number of correct touches pre/posttests Both groups made fewer errors on posttest Experimental group made fewest errors.
Sidman, Cresson, & Willson-Morris 1974	2 males severely retarded Subject 1 2 CA 14 18 MA 4 4 See/touch pictures and words	Circular s: center c: edges	Read projector Tape loop Chimes	Number of correct matches Different numbers of choices used with each subject yet not addressed in findings Mediated transfer - equivalences required prior oral naming Visual to visual training yielded crossmodal results

Table 2-4--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Sidman & Tailby 1982	7 male 1 female nonhandi-capped CA 5-0 to 7-5 See/touch	Circular s: center c: lower 5 circles	Slide projector Solid-state programming Impulse counters 20-pen operations recorder Audiotape	Number of correct choises Equivalence classes can be expanded in either direction. Multiple numbers of direct stimulus relations without training common sample or choice

Note. Tables categorized by numbers of choices and sequenced by year and author.
a."s" denotes sample; "c" denotes choice

subjects demonstrated mediated transfer (oral naming) to additional equivalence classes. Intramodal training (visual to visual) yielded crossmodal (see to say) results. In discussing their findings, Sidman et al. (1974) never mentioned the possible effect that the different number of choices might have had on results.

Six-Choice Matching-to-Sample Studies

Mackay (1985) has conducted the only matching-to-sample study in this review that used a six-choice response choice format (see Table 2-5). Two severely retarded adolescent males were required to see/touch colors and words as well as hear color names/touch color words. Electronic equipment was not used by Mackay. Rectangular pieces of cardboard, pieces of colored paper, and praise in the form of tokens or verbal remarks comprised the materials used in the study. Mackay (1985) supported the use of these materials as being inexpensive, practical, readily available, and easily prepared by retarded students. The cardboard rectangle was divided into 12 sections and the sample stimulus was presented in the top lefthand section. Six response choices appeared randomly in any of the remaining 11 sections. The emergence of equivalence relations as a result of the visual to visual training was reported.

Eight-Choice Matching-to-Sample Studies

Five studies were located in which an eight-choice comparison format was used by investigators. One study (described above and in Table 2-4) by Sidman et al. (1974) included a component in

Table 2-5

Summary of Six-Choice Matching-to-Sample Studies

Author/s	Learner/s Activity	Pattern Arrangement[a]	Equipment	Dependent Variable/s Results
Mackay 1985	2 severely mentally retarded adolescents males See/touch colors/words Hear/touch colors/names	Rectangular (4 x 3) s: upper left corner c: any of 11 other positions	Cardboard Colored paper Tokens Verbal praise	Number of correct touches Equivalence relations formed with symbolic visual to visual training of matching colors to color words

Note. Tables categorized by numbers of choices and sequenced by year and author.
a."s" denotes sample; "c" denotes choice

which one of the two subjects used a five-choice condition and the other subject an eight-choice condition. Studies by Sidman (1969, 1971), Sidman and Cresson (1973), and Sidman and Kirk (1974) used electronic equipment, including a three-by-three matrix response board that had been used in an earlier (non-matching-to-sample) study (Sidman & Stoddard, 1966). Modified for use as a matching-to-sample tool, the matrix provided the learner with the sample choice in the center and later surrounded by eight choices (see Figure 2-17). Sidman used this format in three studies and for part of a third (Sidman & Cresson, 1973). For some reason that was not explained, the format was changed in mid-experiment to a circular arrangement (see Figure 2-18) without, according to the investigators, affecting the results. It can be hypothesized that a possible reason for changing the format might have been the proclivity of learners to demonstrate position habits as previously described with two-choice conditions (Cumming & Berryman, 1961) and four-choice conditions (Saunders & Sherman, 1986). In the original three-by-three matrix, the corner choices were farther away from the sample stimulus than the other choices and also required learner movement on the diagonal, rather than in a horizontal or vertical direction. Placing the response choices in a circle with choices equidistant from each other and the sample stimulus eliminated the potential for bias based upon distance or direction alone. The eight-choice studies (see Table 2-6) were conducted with many

Table 2-6

Summary of Eight-Choice Matching-to-Sample Studies

Author/s	Learner/s Activity	Pattern Arrangement[a]	Equipment	Dependent Variable/s Results
Sidman 1969	4 male 2 female neurologically impaired adults See/touch circles and ellipses	3 x 3 matrix c: center s: edges	Slide projector Microswitch Photocell response 35mm slides Kynmograph recorder Chimes	Number of correct touches Time delay resulted in differences in choices and shift in control
Sidman 1971	Mentally retarded male See/touch printed word/ pictures	3 x 3 matrix s: center c: edges	Slide carousel projector Token dispenser Nova minicomputer programmed procedures Pen/human recorder Tape loop	Number of correct touches Mediated transfer Auditory comprehension Oral Naming

Table 2-6--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Sidman & Cresson 1973	2 males severely retarded See/touch Hear/touch	3 x 3 matrix changed to circle with s: center c: rim	Slide carousel projector Kymographic recorders Chimes	Number of correct touches Training of crossmodal equivalences (visual to visual; auditory to visual) Inability to form equivalences not necessarily related to reading disabilities or lower levels of retardation
Sidman, Cresson & Willson-Morris 1974	2 males severely retarded Subject 1 2 CA 14 18 MA 4 4 See/touch pictures and words	Circular s: center c: edges S 1: 8 S 2: 5	Rear projector Tape loop Chimes	Number of correct matches Different number of choices used with each subject yet not addressed in findings Mediated transfer equivalences required prior oral nameing Visual to visual training yielded crossmodal results

Table 2-6--continued

Author/s	Learner/s Activity	Pattern Arrangement	Equipment	Dependent Variable/s Results
Sidman & Kirk 1974	14 male 1 female reading disabled CA 7-9 to 14-7 years See/touch See/write See/say	3 x 3 matrix s: center c: edges	Slide carousel projector Chimes Token dispenser Nova minicomputer programmed procedures Pen/human recorder Tape loop	Number of correct matches Identity/nonidentity Simultaneous/delayed Emergence of oral naming Procedure did not remediate letter reversals as effectively as writing or naming

Note. Tables categorized by numbers of choices and sequenced by year and author.
a."s" denotes sample; "c" denotes choice

types of learners and were primarily used from 1969-1974 to either corroborate or expand upon the work on stimulus equivalence and mediated transfer.

Implications for Control of Numbers of Choices

A search for matching-to-sample studies conducted from 1950 into 1987 resulted in 43 major studies in which this procedure was used. When the studies are considered in terms of the numbers of response choices given to the learner, it is obvious that an overwhelming number of investigations have incorporated the two-choice condition (see Figure 2-19). This dependence on the two-choice format has remained relatively constant throughout the last four decades. Although consideration of number of elements has been a concern of researchers in various fields (Brennan et al., 1966; Fantz & Fagan, 1975; Hershenson, 1964; Miller, 1968; Miranda & Fantz, 1971) the optimum number of choices has remained unclear.

Sidman (1987) has recently stated a more specific concern with regard to the numbers of choices used in the matching-to-sample procedure. This concern arose initially from careful analysis of potential errors of interpretation when only two choices are given. Most of Sidman's early matching-to-sample studies incorporated a matrix or circular pattern with eight response options surrounding a center sample choice (see Figures 2-17 and 2-18) in symbolic matching tasks. Findings of stimulus equivalence (untrained performances) resulted in the

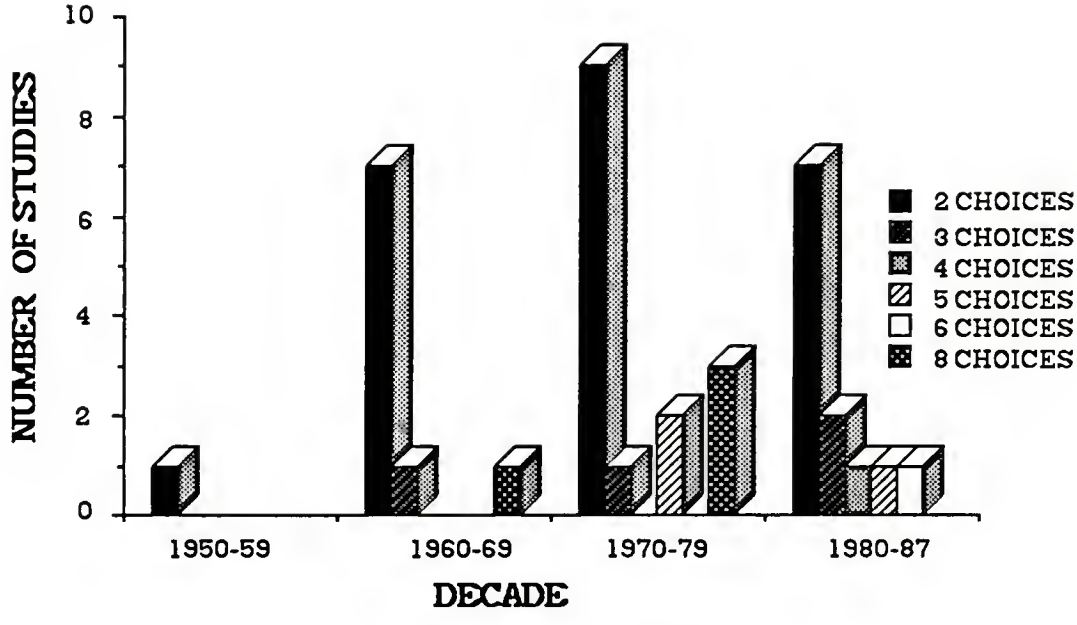

Figure 2-19. Frequency of matching-to-sample studies.

development of testing procedures that were needed to validate the unexplained learning. With eight response choices, pretesting became a time-consuming and unwieldy process. Therefore, many of the subsequent studies, reverted to the earlier two-choice matching patterns. Questions regarding possible misinterpretation due to the presence of false negatives (failure to learn the original discrimination), false positives (selection based simply on the fact that the stimulus is the "other" one), and exclusion (selection as a by-product of excluding the alternate choice) led Sidman to question seriously the validity of using only two choices. Sidman has stated that as the size of the stimulus class increases, the opportunity for false positives decreases and the opportunity for selection by choice increases. This concern has increased validity when consideration is given to the fact that two-choice conditions in the matching-to-sample remain the most frequently-used format.

The speed and dependability of learning across situations may also be related to the number of nonexamples that are provided when making new discriminations. If greater numbers of choices are presented in the matching-to-sample procedure, greater numbers of controlled nonexamples are possible and the learner may have a better chance to develop discriminations that generalize and maintain over time (Engelmann & Carnine, 1982; Moore & Goldiamond, 1964).

Summary

As Sidman (1987) has stated, attention to sound methodology provides the foundation for valid research and effective application. Accurate definitions of stimuli may reduce confounded conclusions regarding learning. This study, therefore, focused on one procedural variable, the number of response choices, and explored whether differences existed in the matching-to-sample performances generated under three- and six-choice conditions with preschool learners. As no previous experimental work in this area existed, the results of this investigation may have great significance, expecially with the anticipated increased application of the matching-to-sample procedure via the microcomputer.

CHAPTER III
METHOD

A study of the effects of the number of choices on performance in matching-to-sample instruction was implemented. Picture-word matching acquisition skills were the focus of the study to assist in subsequent development of instructional materials and strategies that are effective across learners. The general question was as follows: Are there differences in learner performance in a three-choice as compared to a six-choice condition? The following specific questions were addressed:

1. Does the number of response alternatives affect learning accuracy (percentages of correct responses) during the acquisition of stimulus control?

2. Does the number of response alternatives affect speed of responding during the acquisition of stimulus control?

3. Does the number of response alternatives affect celeration (rate of learning or improvement) during the acquisition of stimulus control?

4. Does the number of response alternatives affect response choice position during the acquisition of stimulus control?

5. Does the number of response alternatives affect learning performance during the maintenance of stimulus control?

Applied behavior analysis procedures were used according to the research method described in this chapter. The subjects, setting, variable under investigation, measurement procedures, experimental design, experimental procedures, materials, data collection, and data analysis are described.

Prior to subject selection, permission to teach the subjects prereading skills was obtained from the Baby Gator Research Review Committee and the University of Florida Institutional Review Board (Committee for the Protection of Human Subjects). Parental permission for the subjects recommended by their preschool teachers was obtained, via letters of consent, prior to pretesting (See Appendix A).

Subject Description

Six preschool subjects participated in the study (see Table 3-1). All subjects were enrolled in the Baby Gator Preschool Program on the University of Florida campus. Preschool-age subjects were selected for participation in this study because manipulations of the independent variables required that subjects be nonreaders. Further, nonhandicapped preschool-age children demonstrate mental ages that compare with those of older handicapped learners.

Subject 1 was a 4-year-old male Caucasian whose home language was English. He had attended preschool for 11.5 months and demonstrated a mental age of 4 years, 3 months.

Table 3-1

Subject Data

Subject Number	Sex	Race	Home Language	Chronological Age[a]	Months in Preschool	PPVT-R Data[b] Raw Score	Standard Score	Mental Age[a]	Percentile	Stanine
1	M	C	English	4-0	11.5	48	105	4-3	63	6
2	M	C	English	4-5	11.0	46	96	4-1	40	5
3	F	C	English	4-3	15.5	46	99	4-1	48	5
4	M	H	Spanish	4-5	12.0	42	89	3-11	24	4
5	F	A	Korean	4-3	12.5	51	105	4-5	63	6
6	F	A	Chinese	4-9	13.0	44	88	4-0	22	3

Note. [a]Expressed in years-months. [b]Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981).

Subject 2 was a 4-year, 5-month-old Caucasian male, whose home language was also English. This subject had attended preschool for 11 months and demonstrated a mental age of 4 years, 1 month.

Subject 3 was a 4-year, 3-month-old Caucasian female who spoke English in her home and had attended preschool for 15.5 months. Her mental age was 4 years, 1 month.

Subject 4 was a 4-year, 5-month-old bilingual Hispanic male whose home language was Spanish. He had attended preschool for 12 months and had a mental age of 3 years, 11 months.

Subject 5 was a 4-year, 3-month-old bilingual Asian female whose home language was Korean. She had attended preschool for 12.5 months and demonstrated a mental age of 4 years, 5 months.

Subject 6 was a 4-year, 9-month-old bilingual Asian female who spoke Chinese in her home. She had attended preschool for 13 months and had a mental age of 4 years.

Setting

The study was conducted in the Baby Gator Research Center for Child Development of the University of Florida in Alachua County. The Baby Gator Research Center for Child Development provided preschool activities for approximately 105 children. This setting was familiar to the subjects as they spent a portion of their normal day in the same environment.

All sessions took place in a quiet conference room (8' x 10') that contained a large conference table (3' x 7') and several student chairs. Equipment was set up in a consistent manner for each session with the subject and investigator sitting side-by-side at the end of the conference table facing the monitor and touchscreen. A videotape camera was positioned as unobtrusively as possible, behind the subject, during two sessions. Each session occurred during the regular preschool day and consisted of individual subject interaction with a computer programmed for matching-to-sample instruction.

Variables Under Investigation

Independent Variable

The number of matching/response alternatives was the independent variable in this investigation.

Matching-to-sample procedures begin with the presentation of a sample stimulus to the subject, followed by the opportunity to select one of several comparison words. In this study, a sample stimulus in picture form was presented to the subject within a rectangle located in the center of the computer screen. When the subject touched the stimulus rectangle, comparison words appeared in six rectangles on the rim of the computer screen in one of two experimental conditions: three choices or six choices. Subject performances were compared under each condition (three- or six-response alternative).

Dependent Variables

The dependent variables in this investigation were the accuracy and speed (response latencies) of the subjects' performance, rate of learning or improvement over time (celeration), and the position of response choices. Accuracy, speed, and response position data are described in percentages. These measures permit quantitative evaluation of the experimental questions. Measurement of both the independent and dependent variables is explained further in the following sections.

Measurement

Independent Variable

Control of the independent variable in the form of procedural reliability was maintained through the use of the computer program. The sequence of presentation of either the three- or six-choice alternative conditions was determined by a computer-directed randomization procedure. The sequence, timing, and reinforcement procedures were replicated exactly in each of the 40 trials per session. A pilot program with one subject was conducted to demonstrate the consistency and reliability of both the computer equipment and the software program, as well as the appropriateness of the task for the proposed subjects.

Dependent Variables

All dependent measures in this study were recorded throughout all instructional sessions. The computer program recorded correct and error responses, response position, and response latencies for each condition. Total response time for each session of 20 trials was recorded by the investigator; corrected performance time was calculated by a separate computer program. Corrected performance time reflected the removal of reinforcement time for correct answers and transition times between the end of a trial and the beginning of presentation of the next picture sample.

Response accuracy, the matching of the written word (comparison) to its corresponding picture (sample), was measured for each condition. The number of correct and incorrect choices across 20 trials for each condition was recorded and represented as percentages of correct responses.

Speed of responding was measured in terms of response latencies across 20 trials. These latencies were ranked and median performances for each condition were determined.

Rates of learning over time were calculated by celerations. Celeration is a standard measure of precision teaching in which the frequencies of correct or error responses for a week are expressed as a ratio. For example, a change in performance from 65 to 75 correct movements per minute would be

expressed as a x1.15 celeration or rate of change across 7 days. This celeration would be interpreted as a 15%/week improvement. Response position choices were recorded for each stimulus picture across 20 trials for each of the two conditions. Each response position in the rectangular rim containing six rectangles was numbered, from one to six (see Figure 3-1). The number of subject responses in each response position was recorded automatically by the computer and presented as percentages of total response opportunities.

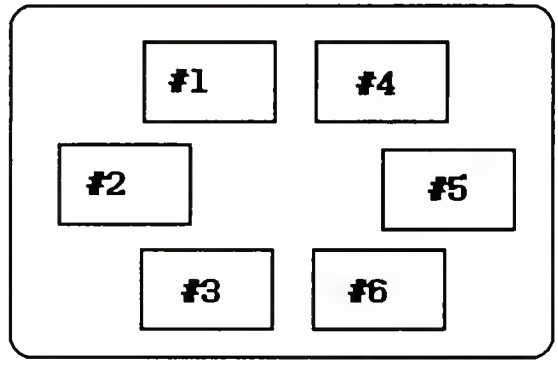

Figure 3-1. Response positions.

Visual inspection of the data was conducted on a daily basis. When a subject demonstrated a difference of at least 10% between the three-choice or six-choice condition, as measured by accuracy or speed data, the experimental condition ended for that subject.

Experimental Design

To compare subject performance and observe differential patterns under two conditions (three-choices and six-choices), each condition needed to be alternated, independent of changes in subject behavior. Further, to minimize maturation and history effects, the presentation of each condition was randomly selected by the computer program for Experiment 1 (English words) and Experiment 2 (Spanish words).

Since the major concern was the control of choice behavior by individuals, a single subject experimental design was the only possibility. Single subject designs permit analysis of controlling variables at the level of the individual and also permit replication within the time and financial resources of the primary investigator.

In this study, learner differences were compared under two experimental conditions in which a matching-to-sample procedure was used. As the subjects were young, the possibility existed that their limited attention spans may have led to early termination of the procedures. Further, within an educational setting, time constraints can be imposed that may reduce the number of opportunities for observing experimental effects.

The alternating treatment design is most appropriate when two or more variables are to be compared. The rapid alternation of conditions counterbalances and minimizes the possibility of confounding by maturation, sequencing, or carry-

over effects. Because the alternating treatments design does not require a baseline phase or the withdrawal of treatment and because results often emerge rapidly, this design is appropriate for young and handicapped subjects. Further, implementation of this design is often more readily accepted by human-service and school personnel. For the researcher using an alternating treatments design, the analysis of more than one independent variable, the investigation of complex behaviors, the possibility of observing reliable treatment effects over time, the minimization of confounding effects or behavioral contrast effects, and the fact that targeted behaviors are unlikely to be reversed provide substantial advantages.

Experimental Procedures

Pretesting

Mental age. Prior to the initiation of Experimental Phase, each subject was administered the Peabody Picture Vocabulary Test-Revised (PPVT-R) (Dunn & Dunn, 1981) to determine mental age and eliminate gross visual and auditory perception deficits. The PPVT-R is an individually administered, norm-referenced measure of receptive (hearing) vocabulary acquisition for Standard American English. This instrument is appropriate for use with subjects in the age range 2.5 to 40 years, who have been exposed to an English-speaking environment. This test has been selected as a well-developed and adequately

standardized instrument with suitable reliability for screening purposes (Salvia & Yssledyke, 1985). Criteria for participation in this study required that subjects demonstrate a mental age within the range of 3 years, 6 months to 4 years, 6 months and have IQs within the normal range of intelligence.

Word recognition. To eliminate the possibility that successful subject performance may have been the result of a student's ability to read selected vocabulary, the Word Recognition Pretest was implemented prior to pretesting for picture knowledge. A detailed description of the Word Recognition Pretest is found in Appendix B. A bank of over 300 words was developed based upon three common basic vocabulary word lists and seven primer and preprimer readers. These words are potentially within the speaking vocabulary of children entering school. From this word bank, those words that occur most frequently across the 10 sources were placed in a primary word bank. A list of these English words and their Spanish counterparts is contained in Appendix C. This primary word list was used to determine a group of 20 words whose English and Spanish counterparts were both visually dissimilar and unable to be read by the subjects. A list of the 20 words used in this study, together with their Spanish counterparts, alternate choices, and criteria for selection are also provided in Appendix C.

Picture knowledge. Young children have a speaking vocabulary of several thousand words (Woods, 1975). For the

purposes of this study, a basic group of 20 words that each subject used when speaking, but was unable to read, was needed for the matching and touching task. The purpose of the picture knowledge subtests was to identify this word list for use in the matching-to-sample procedure. Two forms of pretesting were necessary. In the Picture Naming Pretest, subjects saw and then named a single picture presented on the computer screen. In the Picture Recognition Test, each picture was presented in an array of four pictures at one time. Subjects heard the word and then pointed to a picture. Subjects were required to correctly name and recognize the same 20 pictures. Detailed descriptions of the Picture Naming and Picture Recognition Pretests are presented in Appendix D.

Matching. Each subject was required to demonstrate the ability to do two types of matching, identity and symbolic. Identity matching presents visually identical symbols as samples and comparison matches. In order to participate in picture/word matching tasks in this study, each subject had to be able to focus attention on the picture stimulus and then touch one of several matching picture choices. The purpose of the Identity Matching Pretest was to document successful subject performance in the basic matching-to-sample (touching) procedure, as well as the ability to focus attention on the appropriate stimuli and response choices. A detailed description of the procedure is contained in Appendix E.

In the Symbolic Matching Pretest, each subject demonstrated the ability to match stimuli that were not exactly visually similar, yet were members of the same response class. Upper- and lowercase letters were used in this pretest. A detailed description of the procedure is contained in Appendix E.

Experimental Phase

Sessions were scheduled 5 days per week with a total of 80 trials per session; 20 words were presented twice in English (Experiment 1) and replicated in Spanish (Experiment 2). For each subject, each word was placed randomly either the three-choice or the six-choice condition, 10 words per condition. Each of the 10 words in each condition was then presented two times per session. The computer presented the two experimental conditions in random order to counterbalance presentation and eliminate possible sequencing effects.

A single experimental trial began when the computer presented the sample, a picture stimulus (e.g., a picture in the center of the monitor screen). When the subject touched the sample picture within the frame of the rectangle, either three or six words appeared in the outside rim. The subject responded by touching one of the matching windows on the outside rim. If the subject touched within the correct matching rectangle, a star blinked rapidly within the center rectangle and the response was recorded as correct. This screen then disappeared, ending this experimental trial. If the subject touched any other screen

location, the star did not blink and the response was recorded as an error. This screen disappeared and a new trial began.

Forty trials were included within each of two experiments. Stimulus and response choices continued with picture/English word trials for 40 correct responses (Experiment 1) and were then replicated (Experiment 2) with their picture/Spanish word counterparts.

Experiment 2 was a within-subject systematic replication. In the first experiment, pictures were matched to English words. In the second experiment, the same pictures were matched to Spanish words. Detailed descriptions of Data Collection Procedures for the Experimental and Maintenance Phases are contained in Appendix F.

The computer program served as the instructor, and the principle investigator as the observer for the study. Primary student performance data collection were recorded and stored by the microcomputer program. The instructor also recorded total times for each condition and collected data via videotape recording of two sessions for the purpose of presenting accurate descriptions of student behavior during experimental sessions. The Experimental Phase of this study was concluded when the investigator determined from the data that the manipulation of the independent variable did or did not have a differential effect on subject learning. A difference of at least 10% in the

variables (accuracy or rate) resulted in the termination of the Experimental Phase.

Maintenance Phase

Two weeks following the conclusion of the Experimental Phase, subjects were asked to repeat that component of this study for a single session of 80 trials. The set of 20 pictures used by each subject during the main experiment was presented in the three-choice and the six-choice condition, 10 words per condition. The order of presentation of the two experimental conditions (three-choice/six-choice) was randomly determined. Comparisons to previously collected measures of response accuracy, latency, and position were then made.

Materials

The implementation of this study required the development of several forms of materials. Reliability and implementation procedures were facilitated by the use of existing technological hardware.

Instructional Materials

A variety of materials were developed for the Pretest and Experimental and Maintenance Phase components of this study. Because the matching-to-sample procedure used vocabulary commonly found in young children of school-entry age, criteria were established for the development of a basic word list. A preliminary word bank of 340 words was created from basic word lists (Madden-Carlson and Common Nouns, 1987; McCarr, 1987),

preprimer and primer reading series (Clymer, 1976; Durr, LePere, & Alsin, 1974; Early, 1974; Moving On, 1973; Otto, Rudolph, Smith, & Witson, 1975a,b,c; Rowland, 1979;), the Picture Vocabulary subtest of the Brigance Diagnostic Inventory of Early Development (Brigance, 1978), and two picture dictionaries published for young children (Bennett, 1977; Ogle & Thoburn, 1976). Only nouns that described commonly used objects were selected in order to facilitate the development of corresponding pictures. Only words that were contained in at least two of the above sources were selected for inclusion in the preliminary word list for this study. A second word list of both English (Experiment 1) and Spanish words (Experiment 2) was developed that included only words with a minimum of three and a maximum of six letters. Synonyms, as well as compound and hyphenated words were eliminated. English and Spanish counterparts were then compared to eliminate words that contained either an equal number of letters or more than two adjacent letters that were similar. From this list, the final working word list of 20 words used in this study was selected.

Computer Program

A computer program was written that included Pretest, Experimental, and Maintenance components; the program also recorded and stored data regarding subject performance. For the Word Identification Pretest, the program presented 20 vocabulary words from the working word list described above. Each word was

placed in isolation on the computer screen. The rate of word presentation was controlled by the investigator who pressed a key on the keyboard to present a new word. Subject responses were recorded by the investigator. For the Picture Naming and Recognition Pretests, pictures of the 20 words were presented in isolation and in arrays of four, respectively. For the Experimental and Maintenance Phases, the computer program controlled the presentation of the pictures and words on the screen. Each outer rectangle was equidistant from the adjacent choice rectangles as well as from the center sample rectangle. Distances were measured from the center of each rectangle. Subject responses for each trial were recorded in individual subject files on the program disk. These programs were written in Beginners All-Purpose Symbolic Instructional Code (BASIC) and machine assembly language using the Touch Window Tool Kit. Additional information regarding the design of the computer program can be obtained from the principal investigator. Materials for the Identity Matching Pretest consisted of 8 1/4 x 7 1/4-in. tagboard cards with pictures of happy and not-happy faces arranged in positions identical to those presented on the computer screen.

Hardware

Subjects participated in this study through the use of several pieces of hardware. An Apple IIc computer was used to run the software program. The computer was connected to a black and white 12". television (Samsung) and a Touch Window (Personal

Touch). A portable Panasonic VCR, camera, and 1/2" inch videotapes were used to record two experimental sessions.

Data Recording and Display Materials

A computer file program automatically recorded the number of correct and error responses, response latencies, and the position of response choices. To save the information to each subject's disk, the investigator entered the file name, subject name and number, session number, experiment number, and date. Total times for each condition (three-choice and six-choice) were recorded by the investigator. Data were transferred from the individual student files to spreadsheet and chart programs for calculation of frequencies, presentation of logarithmic and arithmetic charts and graphs, and visual analysis. Duplicates of each subject's disks were maintained.

Data Collection and Analysis

Data Collection

The raw data for this study were collected and analyzed during daily sessions at Baby Gator Research Center for Child Development. Correct and error responses, position responses, and response speeds were recorded for Experiment 1, in which subjects matched pictures with English words and for Experiment 2, a replication, in which subjects matched the same pictures with Spanish words. In each experiment, data were recorded for each subject for each experimental trial across two

conditions of the independent variable. Subjects completed 80 trials per session.

Data Analysis

Performance data for each subject were summarized, graphed, and charted to facilitate the evaluation of the effects of the three- and six-choice treatments on a daily basis. The number of correct and error responses, response latencies (in seconds), response position choices, and total time for each condition were recorded.

Experimental Phase. Accuracy of performance was evaluated in terms of percentages of correct responses for each condition for each subject. Percentages of corrects were calculated by dividing the number of correct responses by 20 (the number of trials for each condition). Data for each condition were then ranked and the median percentages noted.

Performance speed was evaluated by comparing median response latencies for each condition. Daily median latencies were transformed into percentages of difference by subtracting the smaller from the larger median latency and dividing the difference by the larger. This figure was then multiplied by 100 to transform the decimal into a percentage.

Celerations were determined by dividing the number of correct movements per minute for the last session by the median of correct movements per minute for the first three sessions. This figure was then raised to a power of seven divided by the total

number of calendar days. Correct movements per minute per week as described above were graphed on logarithmic charts for visual analysis of learning over time.

Response choice positions were recorded by the computer and the observer and transformed by a computer program into percentages of responses for each position. Instances wherein subjects failed to follow procedures were recorded as procedural errors. These errors included such movements as pressing the sample (center position) instead of a choice position (rim position), touching the center position an extended period of time, or accidental bumping against the touchscreen. A standard for computer placement of correct responses was determined by the observer by recording the position of correct responses across 10 sessions. Individual subject responses were subsequently compared to this standard; henceforth, this standard will be referred to as the computer standard.

Visual analysis of data included the daily comparison of accuracy, speed, and position data to determine the influence of the respective conditions of the independent variable. Careful attention and adherence to procedures prevented the loss of any information or the creation of artificial information during the transformation of the data.

Maintenance Phase. Accuracy, speed, and response choice position data obtained during the Maintenance Phase were calculated as noted above. Accuracy and speed data were

compared to median performance levels for the last 3 days of the Experimental Phase. Response choice data were compared to the computer standard and subject performance during the Experimental Phase.

Summary

The purpose of this study was to examine the effects that the number of comparison choices had on the acquisition of matching-to-sample learning. Six children were exposed to experimental conditions in which they could match a word to its corresponding picture via a matching-to-sample procedure. Correct responses and response latencies were used as primary measures of student performance. The consistency and accuracy of all procedures for implementing the independent variable and recording the dependent variable were maintained through the use of the computer. Raw data were recorded continuously and displayed visually for daily inspection and analysis. The following chapter contains the results of this study. Subject performances are organized according to the questions proposed in Chapter 1 and compared across conditions (the number of matching opportunities) and experiments.

CHAPTER IV
RESULTS

A total of 120 Experimental Phase and 12 Maintenance Phase sessions that incorporated 4800 and 480 trials respectively were conducted across two experiments for each of the six subjects. The number of sessions and data days, according to subject, are presented in the first three columns of Table 4-1. Experimental sessions and corresponding data days varied across subjects due to attendance variations and the rate at which subjects met the criterion difference of 10% between the three- and six-choice conditions. Data collection for each subject was terminated when median differences of at least 10% were noted in accuracy or speed. If these levels of performance were not achieved within 15 sessions, decisions regarding termination would have been made on an individual subject basis. Results are discussed according to the five related questions that have been posed with regard to learning performance.

Accuracy of Responding

All learners demonstrated superior accuracy of responding in the three-choice as compared to the six-choice condition (see Table 4-1). This finding is based upon median differences greater than 10% between the two experimental conditions. In

Table 4-1

Differences in Accuracy of Performance Between Three- and Six- Choice Conditions

Subject	Sessions	Days	Exp.	Condition	Range[a]	Median[a]	% of three-choice superiority[a,b]
1	11	10	1	3	20 to 50	40	
				6	0 to 45	25	15
			2	3	15 to 60	30	
				6	10 to 25	15	15
2	10	11	1	3	20 to 60	30	
				6	5 to 60	23	7
			2	3	20 to 60	40	
				6	10 to 50	18	22
3	9	8	1	3	25 to 40	30	
				6	10 to 35	15	15
			2	3	10 to 45	30	
				6	10 to 30	20	10
4	9	8	1	3	5 to 50	40	
				6	20 to 40	25	15
			2	3	25 to 65	50	
				6	15 to 50	30	20
5	10	11	1	3	25 to 60	50	
				6	10 to 35	20	30
			2	3	15 to 55	30	
				6	0 to 40	20	10
6	11	9	1	3	20 to 50	40	
				6	10 to 40	25	15
			2	3	25 to 60	43	
				6	15 to 60	30	23

Note. [a]Expressed as percentages. [b]Three-choice minus six-choice.

Experiment 1, the median accuracy in the three-choice condition was greater than that of the six-choice condition by a range of 7% (S2) through 30% (S5); in Experiment 2, differences ranged from 23% (S5) through 23% (S6). Five subjects in Experiment 1 and all subject in Experiment 2 met the 10% criterion of superior performance with three choices within 8 through 11 days.

As indicated in Figures 4-1 through 4-6, accurate performances by each subject during the three-choice condition exceeded those of the six-choice condition by 92.5% (111 of 120 sessions) in Experiment 1 and by 90.8% (109 of the 120 sessions) in Experiment 2. Subjects demonstrated equal performance in both conditions in 2.5% (6) of the sessions in Experiment 1 and .8% (1) of the sessions in Experiment 2. Superior performances during the six-choice condition were recorded during 5% (6) of the sessions in Experiment 1 and 8.3% (10) of the sessions in Experiment 2. Maximum levels of accuracy in the three-choice condition ranged from 40% through 60% in Experiment 1 and 45 through 65% in Experiment 2.

No subject demonstrated maximum performance levels in the six-choice condition that exceeded their maximum performance levels in the three-choice condition. Differences between maximum performance levels in the two conditions ranged from 5% through 24% in Experiment 1 and from 10% through 35% in Experiment 2. Only two subjects (S2 and S6) performed equally in both conditions, but these performances were never replicated.

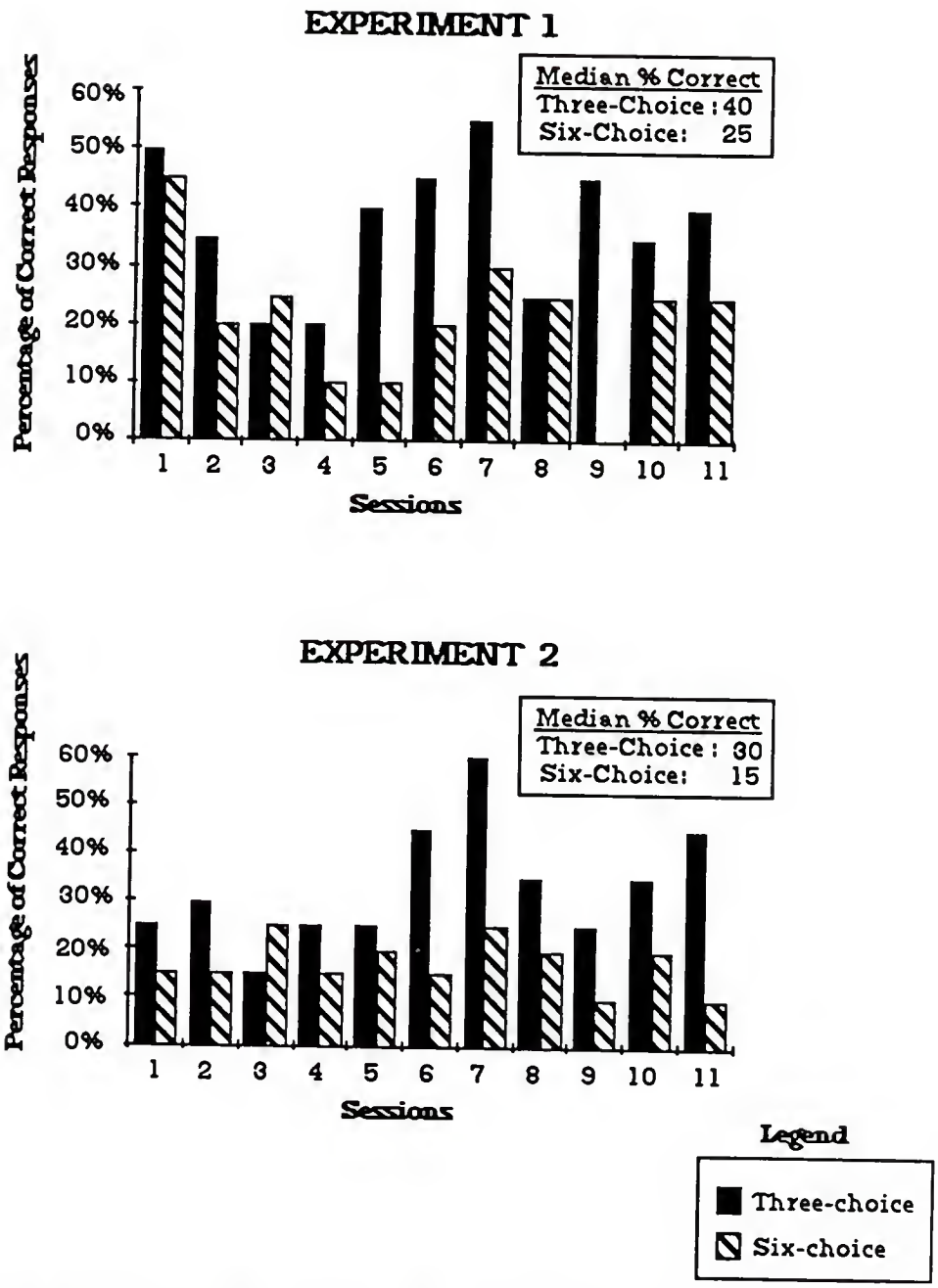

Figure 4-1. Subject 1: Accuracy of responding in the three- and six-choice conditions by sessions.

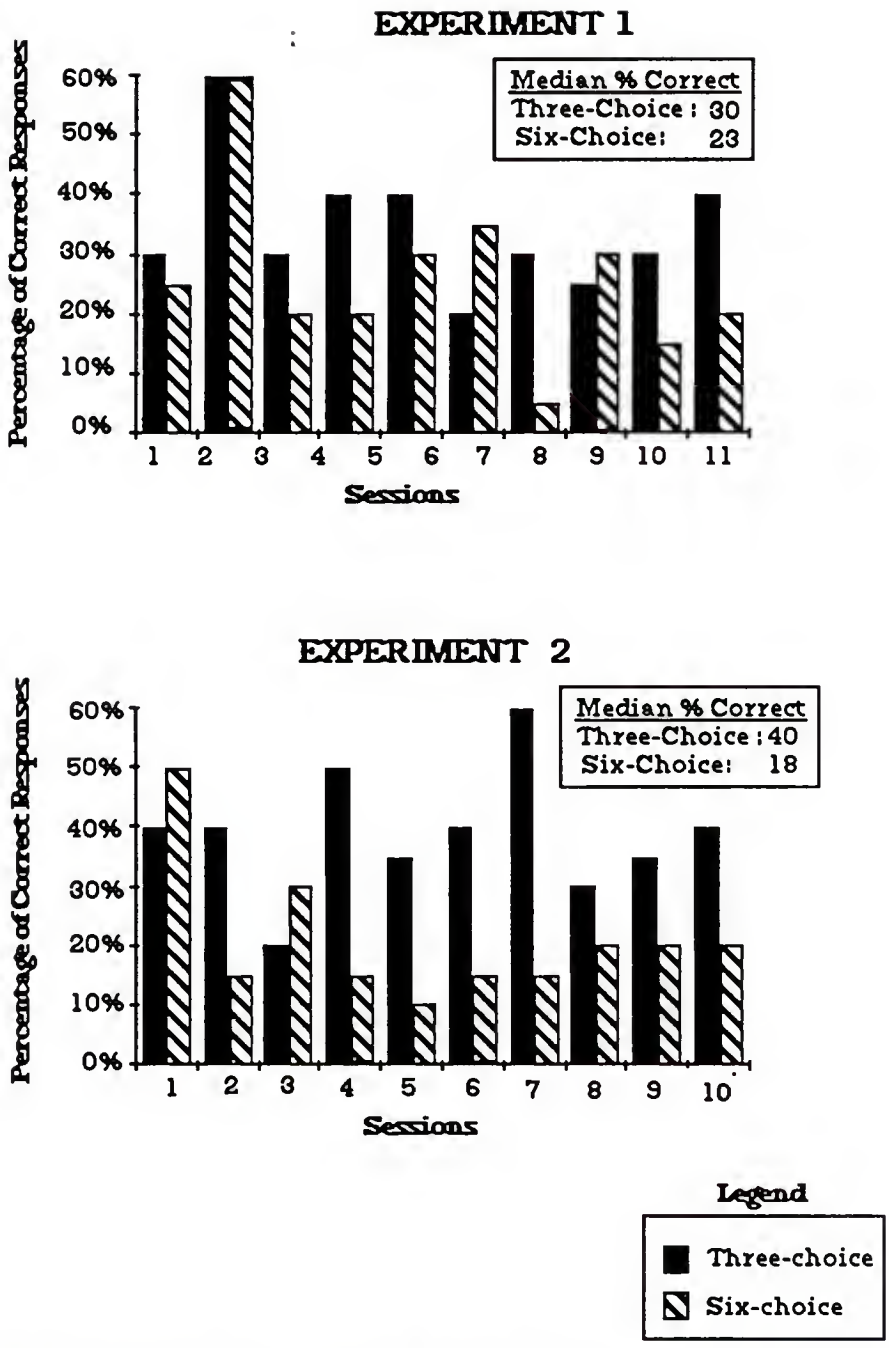

Figure 4-2. Subject 2: Accuracy of responding in the three- and six-choice conditions by sessions.

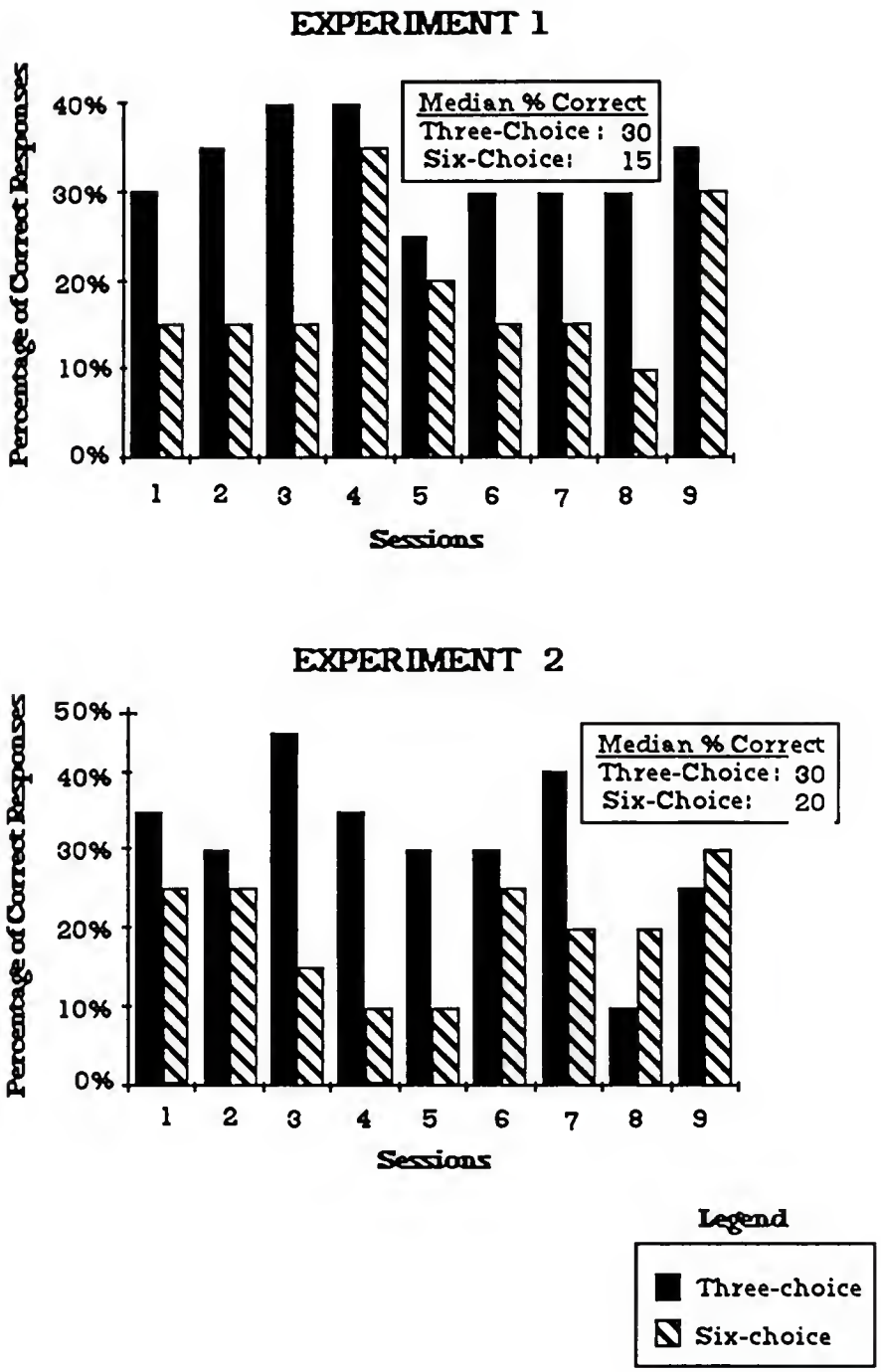

Figure 4-3. Subject 3: Accuracy of responding in the three- and six-choice conditions by sessions.

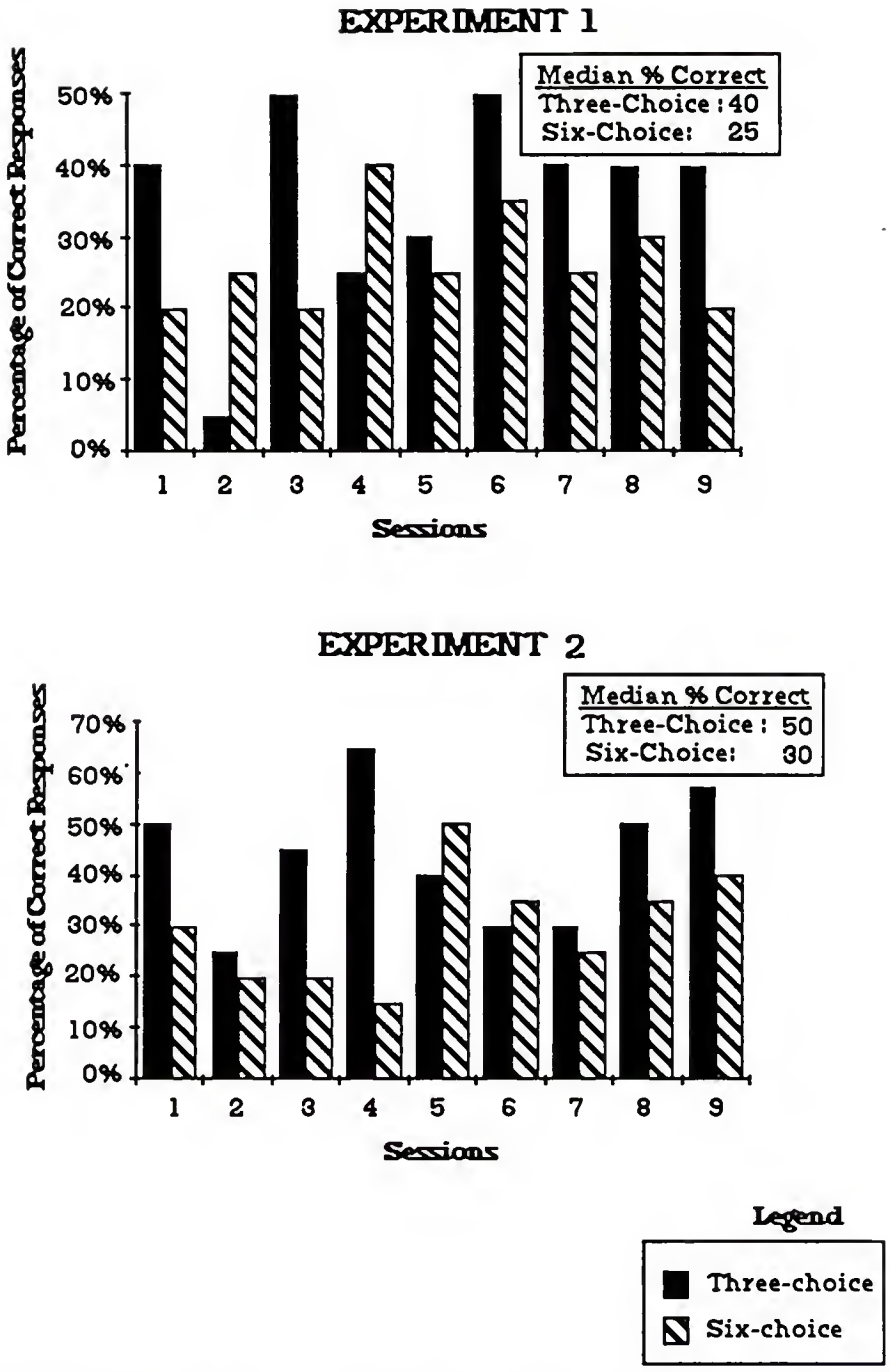

Figure 4-4. Subject 4: Accuracy of responding in the three- and six-choice conditions by sessions.

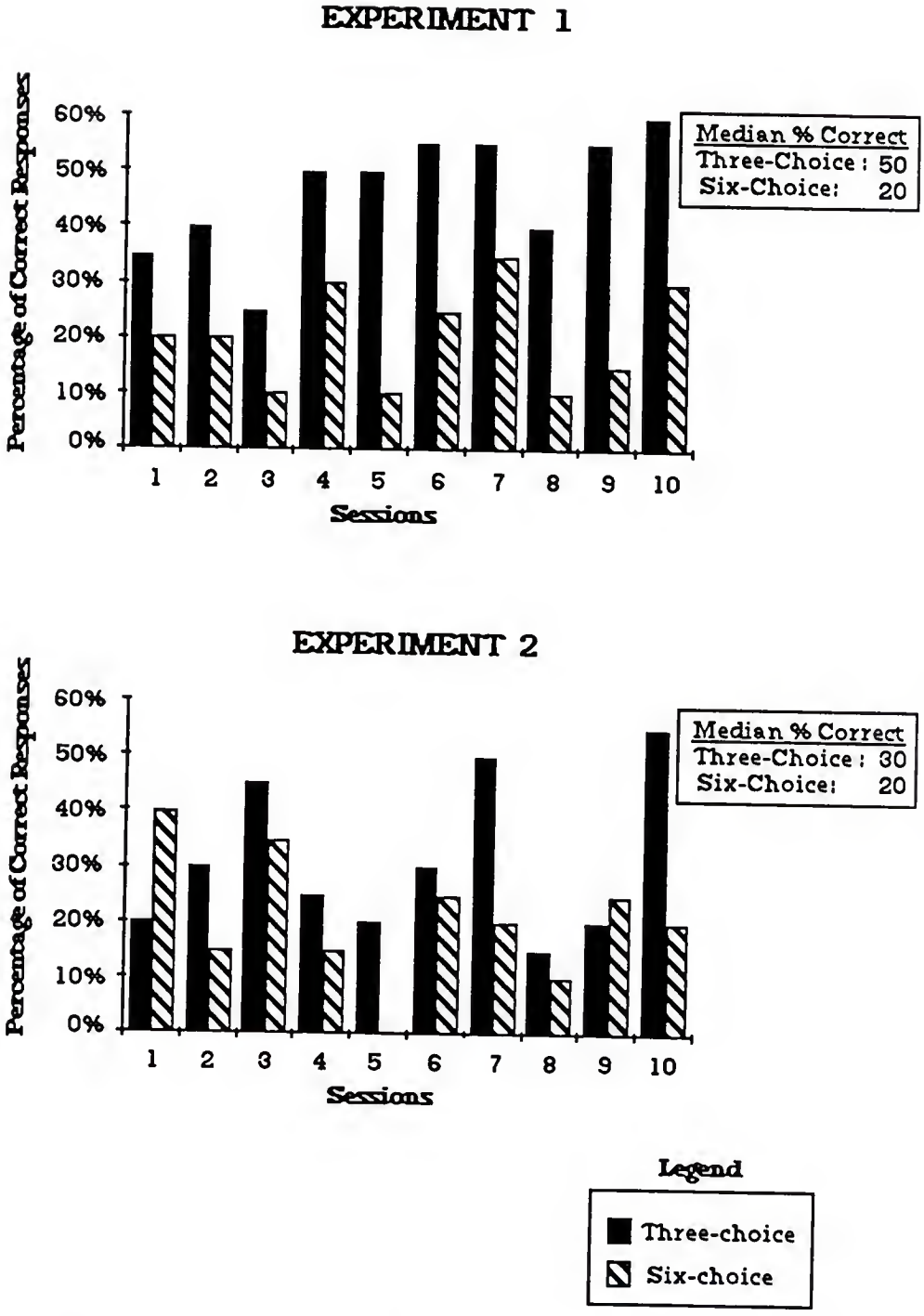

Figure 4-5. Subject 5: Accuracy of responding in the three- and six-choice conditions by sessions.

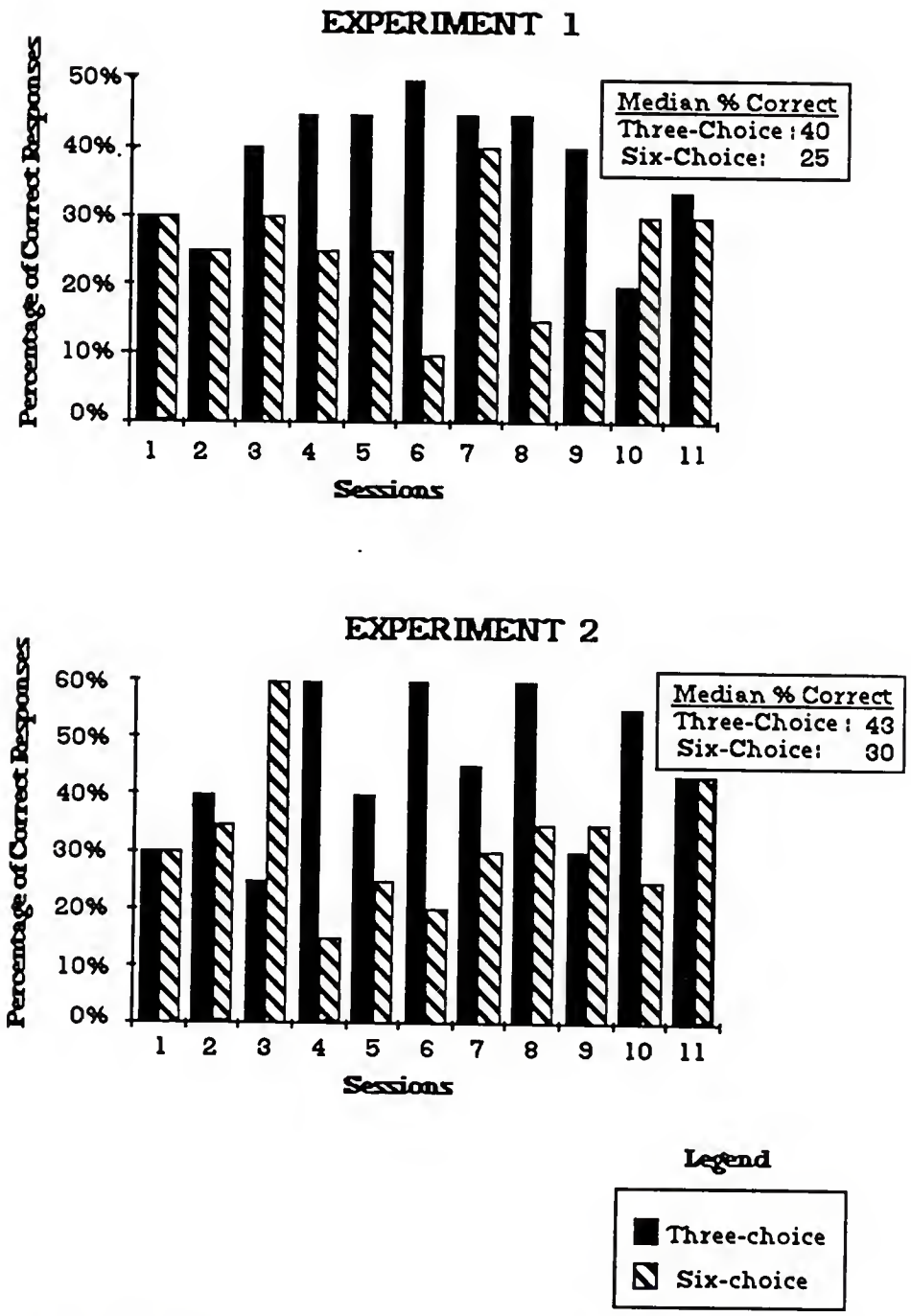

Figure 4-6. Subject 6: Accuracy of responding in the three- and six-choice conditions by sessions.

In summary, all subjects responded at least 10% more accurately with three choices than they did with with six choices in one experiment. All but one subject met the criterion in both experiments.

Speed of Responding

Median Response Latencies.

Longer response latencies in the three-choice condition were exhibited by all subjects in Experiment 1 and by five subjects in Experiment 2 (see Table 4-2). Five subjects exhibited latencies that were at least 10% longer in the three-choice condition in both Experiments. No differences in latencies between the three-choice and the six-choice condition in Experiment 2 were exhibited by Subject 2. In Experiment 1, median response latencies ranged from 1.6 (S5) through 2.6 (S1) seconds in the three-choice condition and from 1.0 (S1) through 1.9 (S2) seconds in the six-choice condition. Response latencies with three choices exceeded those with six choices by a range of 18% (S4) through 42% (S1) with a median of 20%. In Experiment 2, median response latencies ranged from 1.6 (S3 and S6) through 2.6 (S1) seconds in the three-choice condition and from 1.3 (S6) through 2.2 (S1 and S2) seconds in the six-choice condition. Three-choice median latencies ranged from 0% (S2) through 26% (S5) longer than six-choice latencies with a median of 17%. In Experiment 1, no subject demonstrated shorter median response latencies with

Table 4-2

Differences in Speed of Performance Between Three- and Six-Choice Conditions

Subject	Experiment	Condition	Range[a]	Median[a]	% of three-choice superiority[b]
1	1	3	1.8 to 3.5	2.6	
		6	1.0 to 2.5	1.5	42
	2	3	2.1 to 3.8	2.6	
		6	1.4 to 5.9	2.2	15
2	1	3	1.7 to 3.3	2.0	
		6	1.2 to 3.5	1.9	5
	2	3	1.2 to 4.4	2.2	
		6	1.2 to 2.5	2.2	0
3	1	3	1.6 to 2.2	1.9	
		6	1.2 to 1.7	1.5	21
	2	3	1.1 to 2.8	1.6	
		6	1.2 to 2.1	1.4	13
4	1	3	1.2 to 3.1	1.7	
		6	1.1 to 2.5	1.4	18
	2	3	1.6 to 2.9	1.9	
		6	1.1 to 2.4	1.5	21
5	1	3	1.1 to 2.2	1.6	
		6	1.0 to 1.9	1.3	19
	2	3	1.1 to 2.4	1.9	
		6	1.0 to 1.4	1.4	26
6	1	3	1.3 to 2.2	1.8	
		6	1.0 to 2.5	1.4	22
	2	3	1.1 to 2.8	1.6	
		6	1.1 to 1.8	1.3	19

Note. [a]Expressed in seconds. [b]Three-choice minus six-choice; difference divided by three-choice and multiplied by 100.

three choices; only one subject (S6) did so in Experiment 2 wherein Subject 2 performed equally well under either condition.

Correct Movements per Minute

Based upon the findings of median response latency data, a further analysis of speed data was undertaken. Response latencies were totaled for each session to calculate a measure of the frequency of correct movements across conditions and experiments. These data are presented in Table 4-3. In Experiment 1, all subjects performed with greater accuracy when given three-choices. In the three-choice condition, correct responses ranged from 6.9 (S1) through 17.1 (S5) movements per minute with a median of 9.4. With six choices, correct responses ranged from 4.7 (S1) through 10.1 (S6) with a median of 7.2 correct movements per minute. The percentage of superiority with three choices ranges from 14% (S2) through 54% (S5) with a median of 29%. In Experiment 2, given three choices, subjects responded in a range of 6.8 (S1) through 15.7 (S6) correct movement per minute with a median of 9.6. Given six choices, responses were with the range of 3.1 (S1) through 11.2 (S6) correct per minute with a median of 7.1. Correct responses with three choices exceeded those with six choices by a range of 5% through 54% (median of 39%) in Experiment 2.

In summary, subjects took longer to respond with three choices than with six choices. When the measure of speed (median response latency) was compared to the measure of accuracy,

Table 4-3

Differences in Movements per Minute Between Three- and Six-Choice Conditions

Subject	Experiment	Condition	Data base[a]	Correct Responses[b] range	median	Superiority Condition	% [c]
1	1	3	10/11	3.2 to 14.4	6.9		
		6		0.0 to 11.0	4.7	3	32
	2	3	10/11	2.7 to 12.7	6.8		
		6		1.7 to 5.4	3.1	3	54
2	1	3	9/10	4.0 to 21.1	8.4		
		6		.8 to 27.6	7.0	3	14
	2	3	8/10	6.0 to 15.4	10.3		
		6		2.1 to 20.8	5.8	3	44
3	1	3	9/9	6.8 to 12.6	9.0		
		6		2.2 to 12.5	6.2	3	31
	2	3	9/9	2.5 to 18.3	9.9		
		6		4.1 to 10.8	5.3	3	46
4	1	3	9/9	1.1 to 16.8	9.8		
		6		5.0 to 18.7	7.3	3	26
	2	3	9/9	5.3 to 19.1	12.3		
		6		4.9 to 14.8	8.3	3	33
5	1	3	8/10	7.4 to 29.3	17.1		
		6		4.2 to 17.3	7.8	3	54
	2	3	10/10	4.0 to 18.1	7.2		
		6		0.0 to 6.7	8.7	6	5
6	1	3	11/11	5.5 to 15.0	12.3		
				2.2 to 19.0	10.1	3	18
	2	3	9/11	7.1 to 20.1	15.7		
		6		5.4 to 13.8	11.2	3	29

Note. As measured by response latency time.

[a]Recorded sessions/participated sessions. [b]Expressed in seconds. [c]Larger median minus smaller median; difference divided by larger median and multiplied by 100.

however, all subjects responded with more correct movements per minute with three choices than when given six choices.

Learning

Learning was measured by changes in the frequency of correct responses over time, specifically, by changes in correct frequencies/week. These data are presented in Table 4-4 and illustrated in Figures 4-7 through 4-12.

The direction of change can be either positive or negative and is expressed as a multiplication ("times") function. Celerations greater than 1.00, such as x1.23, indicate performances that are improving (accelerating) over time; these are illustrated by trend lines that rise. Celerations less than 1.00, such as x .73, indicate decelerating performance and are shown by trend lines that fall. Celerations of 1.00 are charted with horizontal trend lines that indicate no change in performance over time. Learning can be compared across conditions and experiments for each learner on logarithmic charts that illustrate the direction and comparable rates of change for each condition over time (see Figures 4-7 through 4-12).

In Experiment 1, celerations ranged from x1.00 (S2 and S3) to x1.41 (S5) in the three-choice condition and from x.72 (S2) to x1.83 (S3) in the six-choice condition. As indicated by celerations greater than 1.00, three subjects (S1, S5, and S6) improved their performances over time with three choices; two subjects (S3 and S5) did so with six choices. No change over time was demonstrated

Table 4-4

Celerations for Three- and Six-Choice Conditions

Subject	Calendar Days	Experiment	Condition	Celeration
1	11	1	3	x1.25
			6	x1.07
		2	3	x1.21
			6	x .54
2	11	1	3	x1.22
			6	x .82
		2	3	x .86
			6	x .66
3	8	1	3	x .90
			6	x1.66
		2	3	x .64
			6	x1.00
4	8	1	3	x1.35
			6	x .92
		2	3	x1.33
			6	x1.74
5	11	1	3	x1.87
			6	x1.43
		2	3	x1.68
			6	x .84
6	9	1	3	x1.42
			6	x1.51
		2	3	x2.22
			6	x1.47

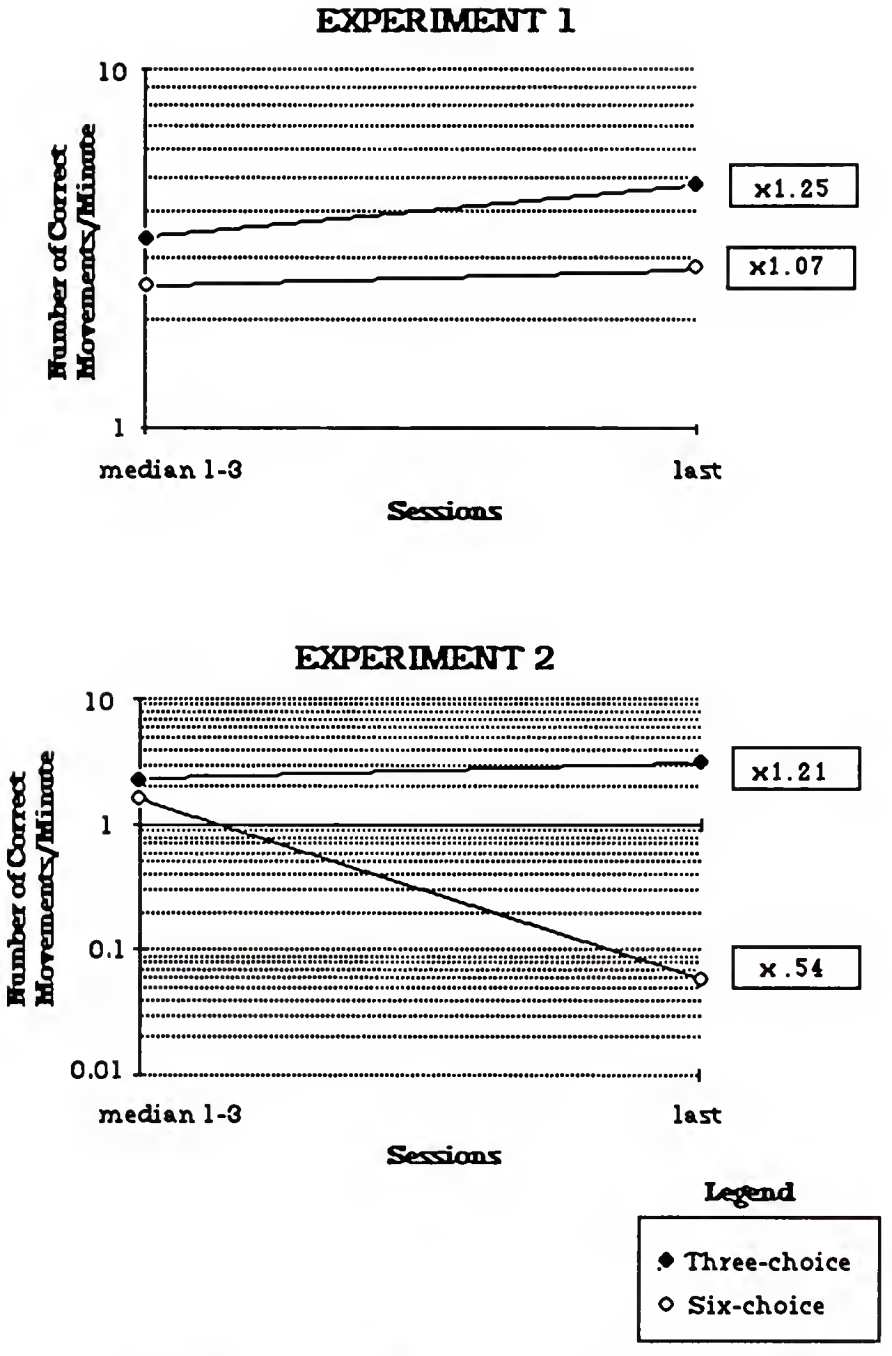

Figure 4-7. Subject 1: Differences in learning between three-and six-choice conditions

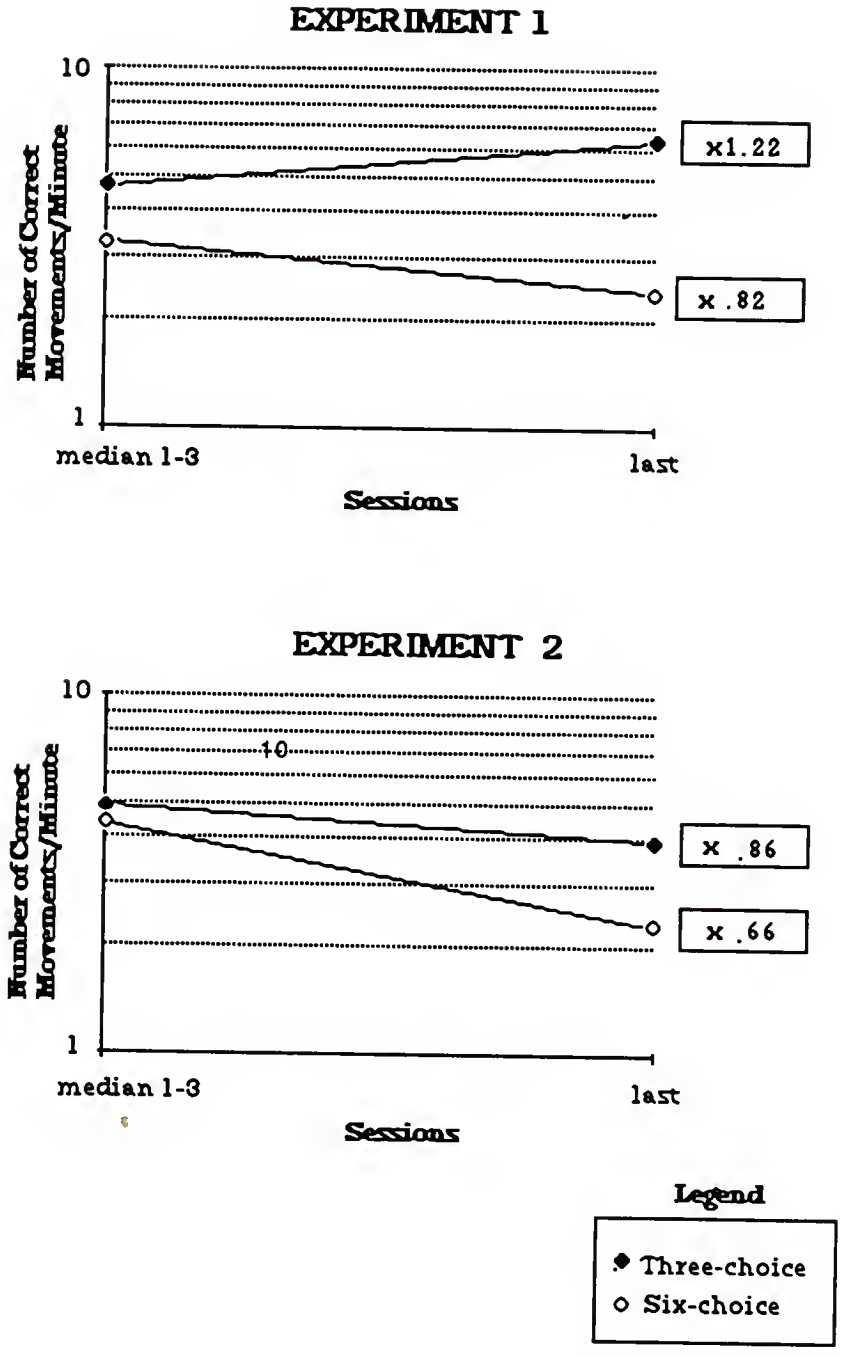

Figure 4-8. Subject 2: Differences in learning between three- and six-choice conditions.

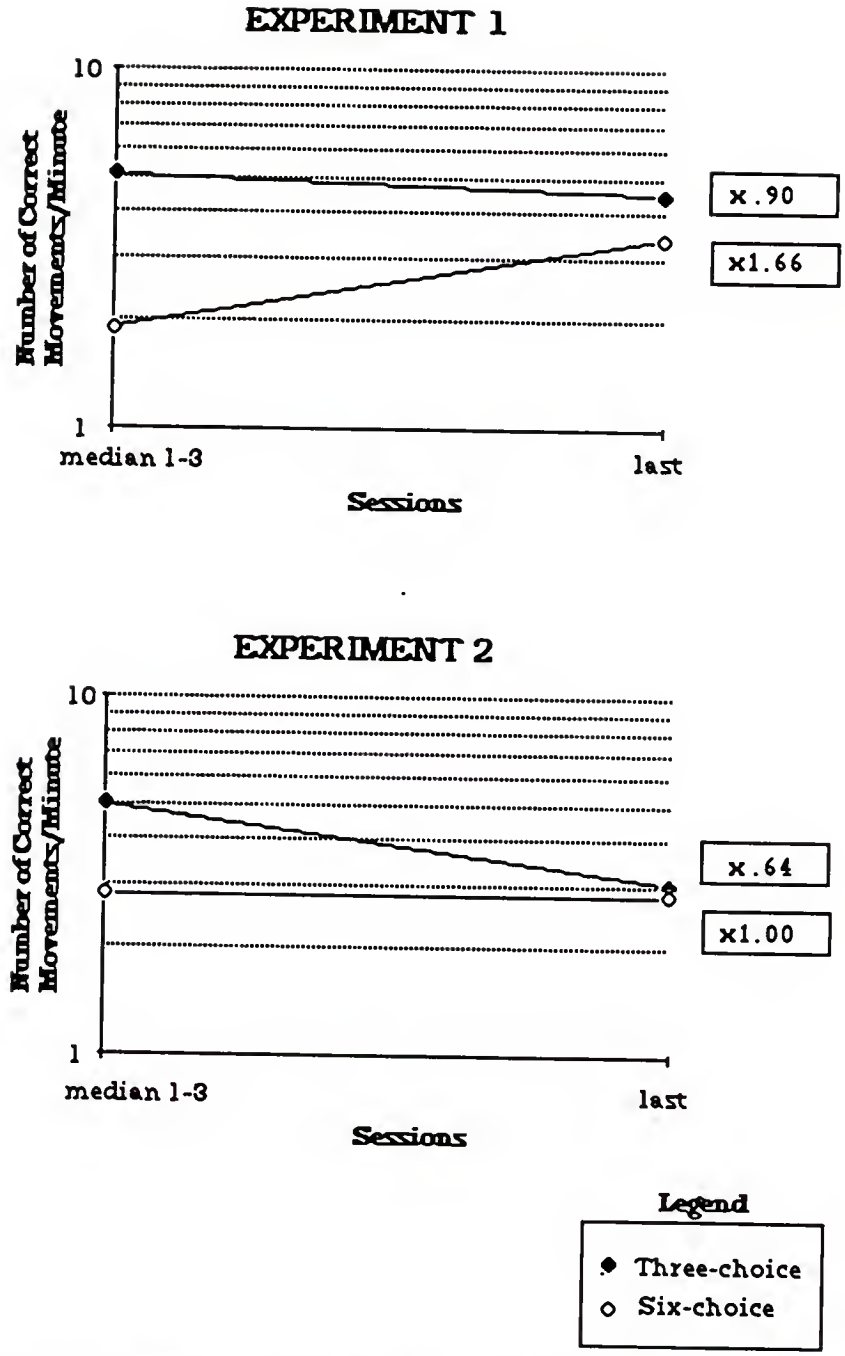

Figure 4-9. Subject 3: Differences in learning between three-and six-choice conditions.

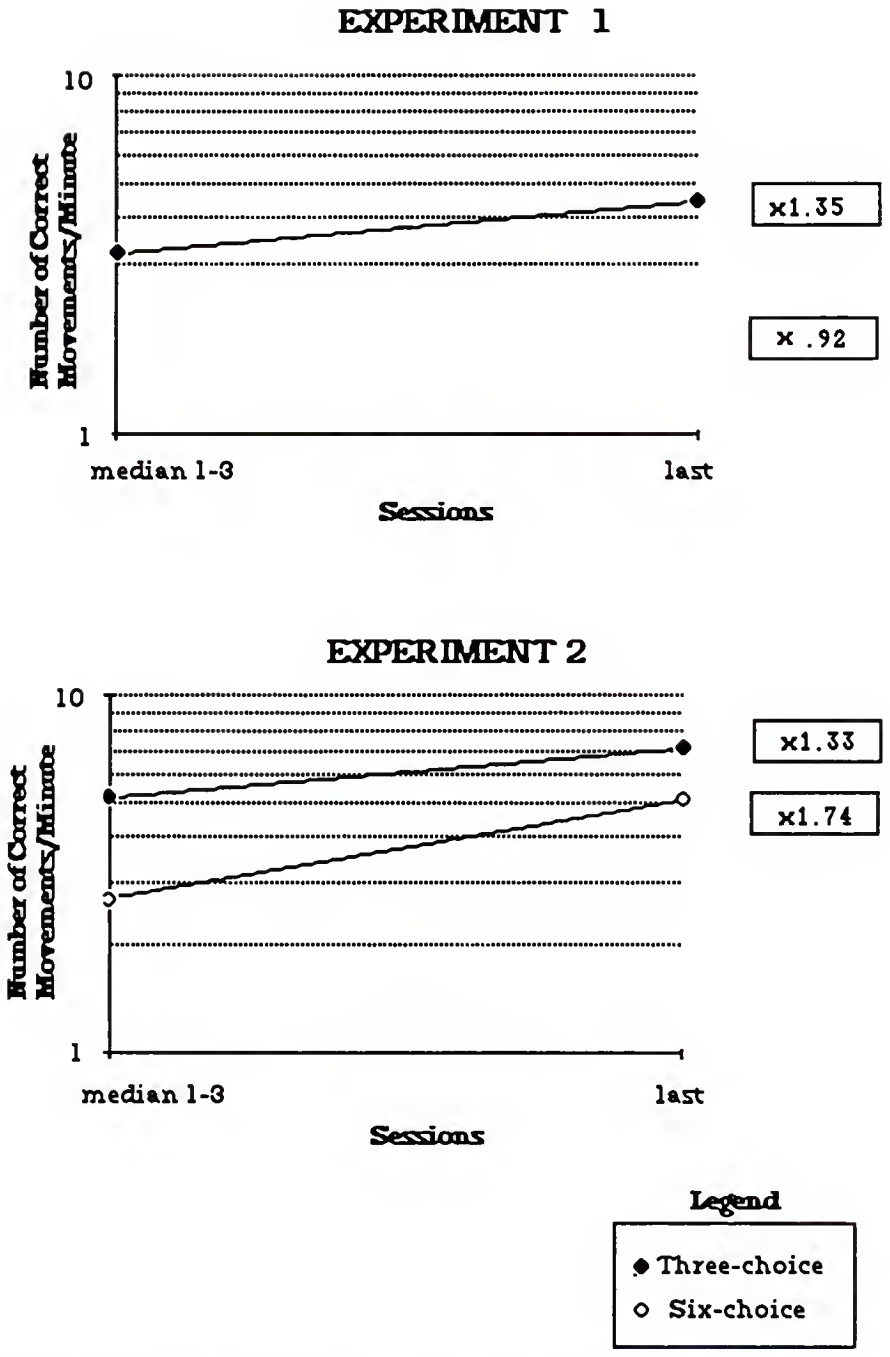

Figure 4-10. Subject 4: Differences in learning between three- and six-choice conditions.

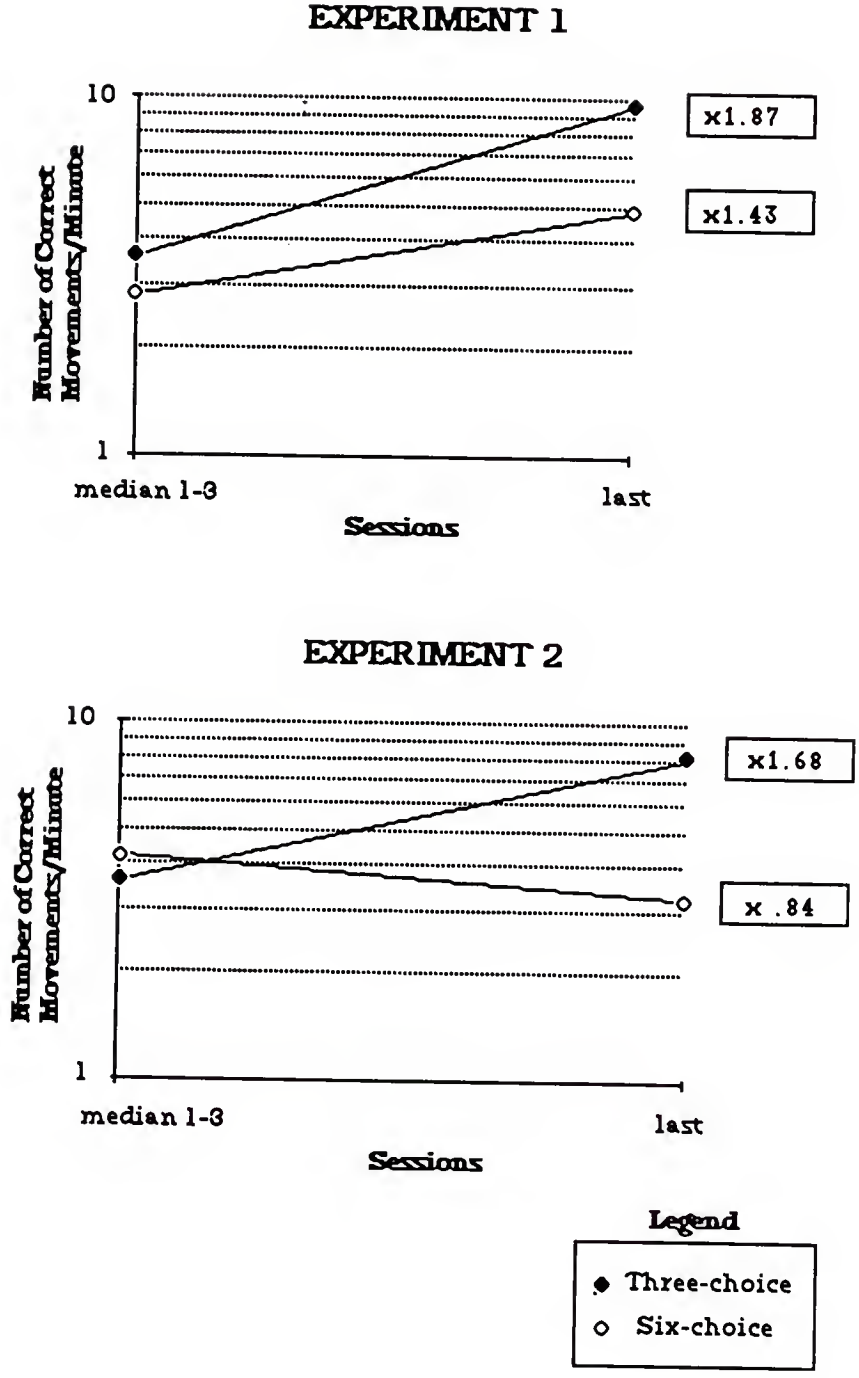

Figure 4-11. Subject 5: Differences in learning between three- and six-choice conditions.

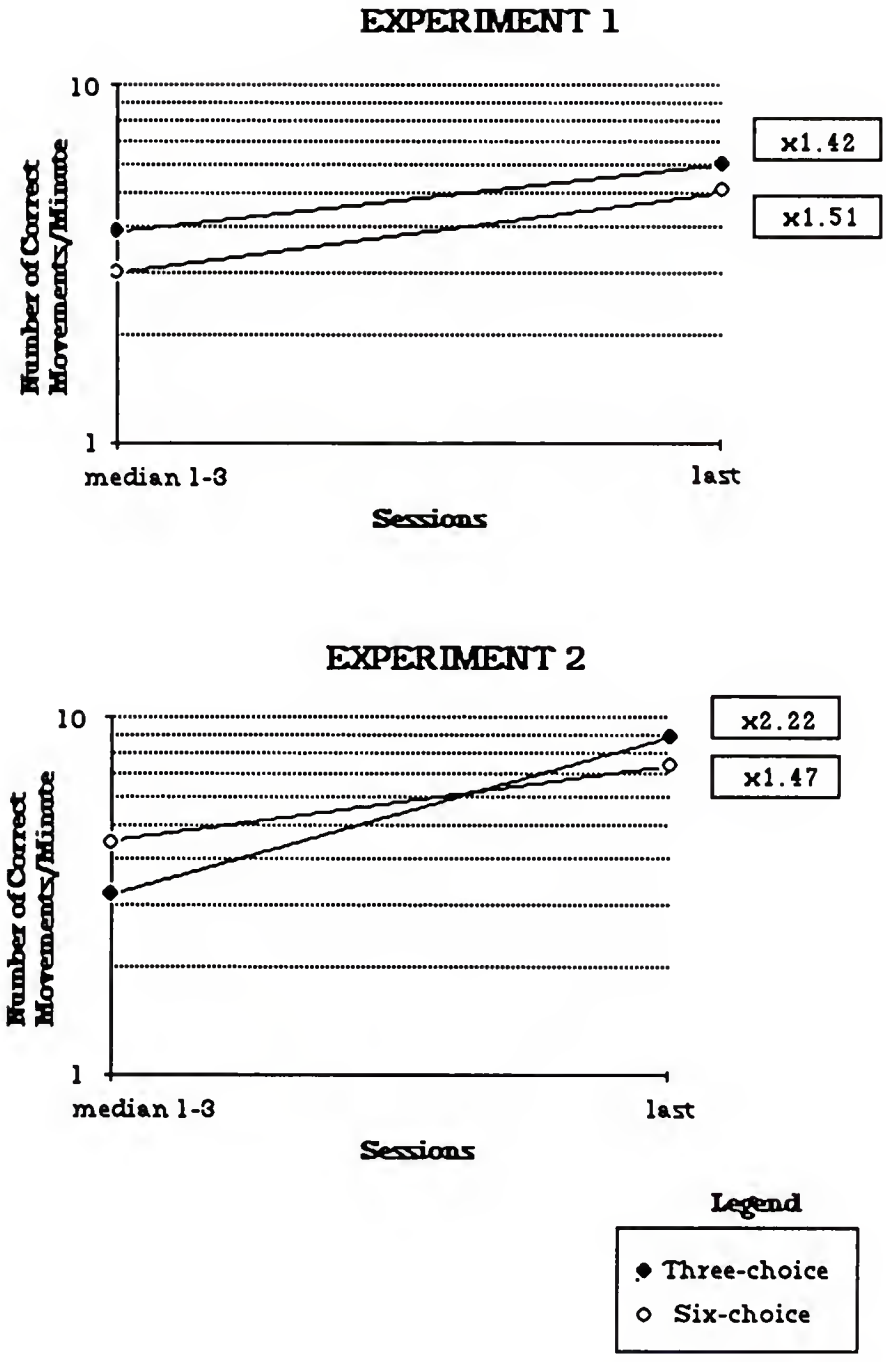

Figure 4-12. Subject 6: Differences in learning between three- and six-choice conditions.

by two subjects (S2 and S3) with three choices and by two subjects (S1 and S6) with six choices. In Experiment 2, celerations in the three-choice condition ranged from x .74 (S3) through x1.45 (S1) and in the six-choice condition from x .70 (S5) through x1.83 (S4). Four subjects (S1, S4, S5, and S6) demonstrated learning (celerations greater than x1.00) with three choices; three subjects (S3, S4, and S6) did so with six choices.

Percentages were used to compare performances in three- and six-choice conditions. With measures of accuracy and response latencies, these differences were obtained by subtracting the smaller percentage in one condition from the larger percentage in the other. In terms of learning, a different method was used. Percentages were obtained by dividing the larger celeration by the smaller and subtracting the digit 1 (see Table 4-7). In Experiment 1, four subjects were more successful with three choices (S1-9%, S2-39%, S5-9%, and S6-13%). Percentages ranged from 83% (S3) with six choices through 39% (S2) with three choices (median of 9% with three choices). In Experiment 2, four subjects (S1-88%, S2-8%, S5-110%, S6-12%) performed better with three choices in a range from 58% (S3) with six choices through 110% (S5) with three choices (median of 9%).

In summary, given three choices, four subjects (S1, S2, S5, and S6) demonstrated learning with three choices that was superior to learning with six choices. These performances were replicated across both experiments.

Position of Response Choices

The position of the correct response choice and the position of the subject's position of response choice were also considered in this investigation. The computer program used a pseudo-random number generator to place correct choices in one of six positions (see Figure 3-1); an equal distribution among the six positions would result in the placement of the correct answer in each position 16.67% of the time. Actual placement percentages were determined by a 10-session sample that served as the standard against which subject response choices were compared (see Table 4-5). These standards ranged from 12% in Position 4 to 21.5% in Position 5. The positions with the lowest frequency for location of the correct choices were Positions 2, 3, and 4; positions with the highest frequency were Positions 1, 5, and 6.

Subject responses were tallied for each response under each condition. Percentages of response choices for Experiments 1 and 2 have been combined and are presented for the three-choice, six-choice, and combined (three- and six-choice conditions) in Table 4-5. Response choices made by Subject 1 (S1) ranged from 7% in Position 2 (P2) to 24% (P4) with procedural errors (described in Chapter III) of 5%. Subject 2's (S2) response choices ranged from 13% (P6) to 21% (P4) with procedural errors of 1%. Subject 3 (S3) made the lowest number of response choices (4%) in Positions 1 (P1) and 2 (P2) and the highest number (48%) of response choices in Position 5 (P5). One percent of the responses were

Table 4-5

Percentages of Response Choice Positions

Three-Choice	Six-Choice	Combined
Computer Standard		
25 7 14 20 17 17	11 17 15 23 14 20	18 12 14.5 21.5 15.5 18.5
Subject 1		
18 23 8 18 14 15	15 25 5 15 8 15	16 24 7 22 11 15
4	5	5 Procedural Errors
Subject 2		
15 19 18 17 16 15	17 23 16 14 18 12	16 21 17 16 17 13
1	0	1 Procedural Errors

Table 4-5--Continued

Three-Choice	Six-Choice	Combined
Computer Standard		
25 7 14 20 17 17	11 17 15 23 14 20	18 12 14.5 21.5 15.5 18.5
Subject 3		
7 21 5 37 12 17	1 19 4 58 6 11	4 20 4 48 9 14
1	1	1 Procedural Errors
Subject 4		
12 28 7 31 3 14	9 39 4 31 4 10	10 33 5 31 4 12
5	3	4 Procedural Errors

Table 4-5--Continued

Three-Choice	Six-Choice	Combined
Computer Standard		
25 7 14 20 17 17	11 17 15 23 14 20	18 12 14.5 21.5 15.5 18.5
Subject 5		
9 15 15 25 15 21	8 17 12 39 8 26	8 16 13 27 11 23
2	1	2 Procedural Errors
Subject 6		
9 21 11 20 17 22	7 23 5 26 17 22	8 22 8 23 17 22
0	0	0 Procedural Errors

procedural errors. Response choices made by Subject 4 (S4) ranged from 4% (P3) through 33% (P4) with 4% procedural errors. Subject 5's (S5) response choices ranged from 8% (P1) through 27% (P5) with procedural errors of 2%. Subject 6 (S6) made lowest number of response choices (8%) in Positions 1 and 2 and the highest number (23%) of response choices in Position 5 (P5). No procedural errors were noted.

Subject responses in each position were compared to the computer standard in the three- and six-choice conditions. Total differences (Positions 1-6) were computed for each condition and the results are displayed in the last two columns of Table 4-6. Three subjects (S1, S2, and S3) demonstrated greater differences from the computer standard with six choices than with three choices. The remaining subjects (S4, S5, and S6) displayed greater differences in the three-choice condition. Deviations from the computer standard have been combined for all positions, transformed into percentages that represent greater numbers of response choices in one condition, and are presented in the last column of Table 4-7. Three subjects (S1, S2, and S3) deviated from the computer standard 10% to 20% (median of 10%) more with six choices than with three choices. The other subjects (S4, S5, and S6) deviated 10% to 60% (median of 40%) more with three choices than with six choices. Performances across conditions were divided equally among the six subjects.

Table 4-6

Differences of Response Choice Positions from Computer Standard

Subject	Response Choice Positions[a]							Combined Positions[b]	
	1	2	3	4	5	6	Procedural	Three-choice	Six-choice
1	- 2.0	- 7.5	- 4.5	+12.0	+ .5	- 3.5	5.0	36	41
2	- 2.0	+ 3.5	+ 1.5	+ 9.0	- 5.5	- 5.5	1.0	32	34
3	-14.0	-10.5	- 6.5	+ 8.0	+27.5	- 4.5	1.0	62	75
4	- 8.0	- 9.5	-11.5	+21.0	+ 9.5	- 6.5	4.0	69	63
5	-10.0	- 1.5	- 4.5	+ 4.0	+ 6.5	+ 4.5	2.0	38	24
6	-10.0	- 6.5	+ 1.5	+10.0	+ 1.5	+ 3.5	0.0	38	28
Med:	- 9.0	- 8.5	- 4.5	+ 9.5	+ 4.0	- 4.0	1.5	38	35

Note. Expressed as percentages.

[a]Three- and six-choice conditions combined. [b]These data are not totals of the adjacent columns.

Table 4-7

Summary of Experimental Phase Performances: Comparisons Between Conditions

Subject	Experiment	Accuracy	Speed	Correct/Minute	Celerations	Response position
1	1	15/3	62/3	32/3	17/3	10/6
	2	15/3	15/3	54/3	124/3	
2	1	7/3	5/3	14/3	49/3	10/6
	2	22/3	0	44/3	30/3	
3	1	15/3	21/3	31/3	84/6	20/6
	2	10/3	13/3	46/3	56/6	
4	1	15/3	18/3	26/3	47/3	10/3
	2	20/3	21/3	33/3	31/6	
5	1	30/3	19/3	54/3	31/3	60/3
	2	10/3	26/3	5/6	100/3	
6	1	15/3	22/3	18/3	6/6	40/3
	2	23/3	19/3	29/3	51/3	
Medians:	1	15/3	21/3	29/3	24/3	
	2	21/3	17/3	39/3	76/3	

Note. Expressed as median percentages of performance superiority in either the three- or six-choice condition (ex: percentage/condition)

Differences from the computer standard were computed for each individual subject in terms of each choice position. These results are displayed in Table 4-6 as negative (fewer than the computer standard) or positive (more frequent than the computer standard). All subjects differed from the computer standard by more than 10% either positively or negatively in at least one position. The largest negative difference was 11.5% (S4) and the largest positive difference was 27.5% (S3). Differences greater than 10% according to response position were found in all positions except Position 6 (P1). Position 1 (P1) was selected less often than the computer standard by all subjects (-14% through -2%). Position 4 (P4) was selected more frequently than the computer standard by all subjects (4% to 21%). The highest difference was located in Position 5 (27.5% for S3). The greatest number of subjects who differed from the computer standard by more than 10% were noted in Position 4 (S1, S4, and S6); the median difference was 9.5%. Subjects deviated from the standard in a negative manner in Positions 1, 2, and 3 (on the left); positive deviations were noted at Positions 4 and 5 (on the right). Subjects selected responses less frequently on the left and more frequently on the right.

Total positive, negative, and combined differences from the computer standard are presented in Table 4-6. Across conditions, Subjects 3 and 4 exhibited the highest differences (69% and 66%)

from the computer standard. All other subjects differed from the computer by a range of 31% to 34%.

In summary, subjects were equally divided as to whether they demonstrated greater differences than the computer standard in the three- or six-choice condition. All subjects differed from the computer standard by at least 10% at each position, with the exception of P6. Two subjects exhibited high total differences from the standard (71% and 66%); four subjects demonstrated much lower differences (median of 32%)

Maintenance

Two weeks following the conclusion of the Experimental Phase, Experiments 1 and 2 were repeated with all subjects. Maintenance data were then analyzed and compared to Experimental Phase data as described above to determine whether differences in learner performance, noted during the Experimental Phase, were maintained across a period of non-instruction. These data are organized according to measurements of accuracy of responding, speed of responding, and response choice position.

Accuracy of Responding

Data that reflect accuracy performances for the Experimental Phase (median of the last three sessions) and the Maintenance Phase are presented in Table 4-8. During the Experimental Phase, five subjects demonstrated accuracy in the three-choice condition that was superior to the six-choice condition in Experiment 1 (S1, S3, S4, S5, and S6) and Experiment 2 (S1, S2, S3, S4, and S6).

Table 4-8

Differences in Accuracy Between Three- and Six-Choice Conditions - Maintenance

Subject	Days[a]	Experiment	Phase						
			Experimental			Maintenance			
			Three[b]	Six[b]	% Diff.[c]	Three[b]	Six[b]	% Diff.[c]	Overall % Change
1	13	1	40	25	+15	35	25	+10	- 5
		2	35	10	+25	40	40	+ 0	- 25
2	13	1	30	30	0	20	35	-15	- 15
		2	35	20	+15	45	10	+35	+ 20
3	16	1	30	15	+15	30	20	+10	- 5
		2	25	20	+ 5	35	10	+25	+ 15
4	16	1	40	30	+10	45	40	+ 5	- 5
		2	50	35	+15	30	30	0	- 15
5	13	1	55	15	+40	45	20	+25	- 15
		2	20	20	0	35	15	+20	+ 20
6	15	1	35	30	+ 5	15	25	-10	- 15
		2	45	35	+10	50	50	0	- 10

Note. [a]Number of intervening days. [b]Choice condition. [c]Positive denotes difference in favor of three-choice condition. Negative denote difference in favor of six-choice condition.

Four subjects (S1, S3, S4, and S6) exhibited this superior performance across experiments. No subject demonstrated superior accuracy in the six-choice condition in either experiment.

During the Maintenance Phase, four subjects (S1, S3, S4, and S5) maintained a superior accuracy in the three-choice condition in Experiment 1; three subjects (S2, S3, and S5) demonstrated higher percentages of correct responses in the three-choice condition in Experiment 2. Two subjects (S3 and S5) were able to maintain this standard of performance difference across experiments. Five subjects (S1, S2, S3, S4, and S5) showed superior three-choice accuracy in at least one experiment. Subject 6 performed with greater accuracy (15%) with six choices during Experiment 1 and displayed no differences between conditions during Experiment 2.

When accuracy differences during the Maintenance Phase were compared to the median accuracy data for the last three days of the Experimental Phase, all subjects exhibited reductions in their accuracy levels in Experiment 1. The range of loss was from 5% through 15%. In Experiment 2, three subjects reduces their levels of accuracy (S1-25%, S4-15%, and S6-10%); three subjects increased their accuracy levels (S2-20%, S3-15%, and S5-20%).

In summary, during the Maintenance Phase, for at least one experiment, most subjects maintained accuracy performance levels that were superior in the three-choice condition. Concomitantly, most subjects showed a reduction in their accuracy performance

levels during the Maintenance Phase compared to the Experimental Phase.

Speed of Responding

Median response latencies. Differences in response latencies between the Experimental and Maintenance Phases are presented in Table 4-9. During the Experimental Phase, most subjects (S1, S2, S3, S4, and S6) exhibited longer response latencies with three choices than with six choices. Differences between conditions ranged from 0% (S5) through 32% (S2) with a median of 19% in Experiment 1 and from 6% (S3) through 31% (S6) with a median of 12% in Experiment 2. Subject 5 performed with response latencies that were equal across conditions in Experiment 1 and 7% longer with six choices during Experiment 2.

When data from the Maintenance Phase were examined, all subjects emulated their Experimental Phase performances. Subjects 1, 2, 3, 4, and 6 demonstrated response latencies that were longer with three choices than with six choices. Percentages of difference ranged from 22% (S3) through 38% (S2) with a median of 28% in Experiment 1 and from 17% (S6) through 55% (S2) with a median of 33% in Experiment 2. Subject 5 performed with longer latencies in the six-choice condition in Experiment 1 (9%) and equal latencies in Experiment 2. Across phases, five subjects lengthened their response latencies with three choices, either in Experiment 1 or in Experiment 2.

Table 4-9

Differences in Speed of Performance Between Three and Six-Choice Conditions - Maintenance

Subject	Days[a]	Experiment	Phase						
			Experimental			Maintenance			
			Three[b]	Six[b]	% Diff.[c]	Three[b]	Six[b]	% Diff.[c]	Overall % Change.[c]
1	13	1	2.8	2.5	18/3	1.9	1.4	26/3	+ 8/3
		2	2.5	2.2	12/3	2.5	1.3	48/3	+36/3
2	13	1	3.1	2.1	32/3	2.9	1.8	38/3	+ 6/3
		2	2.5	2.2	12/3	2.9	1.3	55/3	+43/3
3	16	1	2.0	1.5	25/3	1.8	1.4	22/3	- 3/3
		2	1.6	1.5	6/3	1.9	1.3	32/3	+26/3
4	16	1	1.6	1.3	19/3	1.7	1.2	29/3	+10/3
		2	1.8	1.4	22/3	1.8	1.2	33/3	+11/3
5	13	1	1.4	1.4	0	2.0	2.2	9/6	+ 9/6
		2	1.3	1.4	7/6	2.1	2.1	0	- 7/6
6	15	1	1.4	1.2	14/3	1.9	1.4	26/3	+12/3
		2	1.6	1.1	31/3	1.8	1.5	17/3	- 14/3

Note. [a]Number of intervening days. [b]Choice condition. Expressed in seconds. [c]Larger median minus smaller median; difference divided by larger median and multiplied by 100. Percentages given in terms of longer latency in either the three- or six-choice condition.

In summary, all subjects, with the exception of Subject 5, took longer to respond with three choices, as measured by median response latencies. These longer latencies were observable in both the final sessions of the Experimental Phase and during the Maintenance Phase. Increasing/lengthening latencies for five subjects with three choices are indicated positive overall changes in the last column of Table 4-9.

Correct movements per minute. During the Experimental Phase (median of last three days), in Experiment 1, correct responses ranged from 6.2 through 17.4 (median of 19.9) per minute with three choices and from 5.1 through 19.0 (median of 7.0) per minute with six choices (see Table 4-10). In Experiment 2, correct responses ranged from 4.6 through 12.6 (median of 7.0) per minute in the three-choice condition and from 1.7 through 12.9 (median of 6.4) per minute in the six-choice condition. When differences between conditions were compared for each subject during the Experiment Phase, greater numbers of correct responses were observed for all subjects in at least one experiment. Four subjects (S1, S2, S3, and S4) replicated this performance across experiments.

During the Maintenance Phase, all subjects performed with fewer numbers of correct responses in the three-choice condition in at least one of the two experiments. During Experiment 1, in the three-choice condition, the number of correct responses per

Table 4-10

Differences in Correct Movements Per Minute Between Three- and Six-Choice Conditions - Maintenance

Subject	Days[a]	Experiment	Phase						
			Experimental			Maintenance			
			Three[b]	Six[b]	% Diff.[c]	Three[b]	Six[b]	% Diff.[c]	Overall change[c]
1	13	1	6.2	4.6	26/3	3.7	3.6	3/3	- 23/3
		2	7.0	1.7	15/3	3.2	6.2	48/6	- 63/3
2	13	1	7.5	6.7	11/3	1.4	2.8	50/6	- 61/3
		2	6.2	6.1	2/3	3.1	1.5	52/3	+ 48/3
3	16	1	8.6	5.6	35/3	3.3	2.9	12/3	- 23/3
		2	7.0	5.3	24/3	3.7	1.5	59/3	+ 35/3
4	16	1	12.4	7.3	41/3	5.3	6.7	21/6	- 55/3
		2	15.6	12.3	21/3	3.3	5.0	34/3	+ 13/3
5	13	1	17.4	7.9	55/3	4.5	1.8	60/3	+ 5/3
		2	5.1	6.7	24/6	3.3	2.5	24/3	- 48/6
6	15	1	11.3	12.6	10/6	1.6	3.6	56/6	+ 46/6
		2	19.0	12.9	32/3	5.6	6.7	16/6	- 48/3

Note. [a]Number of intervening days. [b]Choice condition. [c]Percentages given in terms of superiority in either the three- or six-choice condition. Larger frequency minus smaller frequency; difference divided by larger frequency and multiplied by 100.

minute ranged from 1.4 through 5.3, with a median of 3.5, per minute; in the six-choice condition, responses ranged from 3.1 through 5.6 (median of 3.3). :During Experiment 2, the number of correct responses ranged from 1.8 through 6.7 (median of 3.3) per minute with three choices. With six choices, responses ranged from 1.5 through 6.7 (median of 3.8) per minute. When overall changes across phases are compared, most subjects (S1, S2, S3, S4, and S6) exhibited losses in at least one experiment as to the number of correct responses per minute in the three-choice condition.

In summary, most subjects maintained and even increased the length of responding time across Experimental and Maintenance Phases. At the same time, while most subjects were able to maintain some measure of superior performance with three choices, their numbers of correct responses per minute with three choices decreased during the Maintenance Phase.

Response Choice Position

The position of response choices made by subjects during the Maintenance Phases were compared across conditions, first for differences from the computer standard and then for differences from Experimental Phase performances. These results are displayed in Table 4-11. Data from the Experimental Phase reflect the total number of sessions. Individual subject performances during the Maintenance Phase paralleled those of the Experimental

Table 4-11

Differences in Proportion of Responses by Response Choice Position Between Three- and Six-Choice Conditions - Maintenance

Three-Choice	Six-Choice	Sums of Difference

Subject 1

-7	+8
-1	+13
-9	-12

+9	+8
-12	+10
-4	-12

3	6	6/3
50	55	10/6

Subject 2

-5	+6
-14	+15
-9	+8

-8	+11
-15	+22
-11	-22

3	6	6/3
57	68	20/6

Subject 3

+8	+31
-6	-2
-17	-14

+35	+18
-9	-4
-14	-19

3	6	6/3
78	103	30/6

Table 4-11--Continued

Three-Choice	Six-Choice	Sums of Difference

Subject 4

-22	+18
-14	+33
-17	+3

-6	+2
-15	+31
-11	-4

3	6	6/3
107	68	60/3

Subject 5

-20	-7
-6	+20
+6	+8

-20	+3
-1	+15
+2	+6

3	6	6/3
67	47	40/3

Subject 6

-20	+6
-9	+5
+3	+6

-3	+2
-5	+3
+2	+3

3	6	6/3
49	21	130/3

Note. Expressed as percentages.

Phase. Again, Subjects 1, 2, and 3 exhibited higher percentages of difference from the computer standard in the six-choice condition. Subjects 4, 5, and 6 repeated their higher percentages of difference from the computer standard in the six-choice condition.

Performances during the Maintenance Phase were also considered in terms of the degree of change from the Experimental Phase (see Tables 4-12 and 4-14). Subjects 4, 5, and 6 exhibited the greatest percentages of change across phases (median of 50%); Subjects 1, 2, and 3 exhibited the least (median of 10%).

Response choices made by subjects in each condition were combined and considered as deviation from the computer standard according to position. These percentages are presented in Table 4-12 wherein differences can be compared for each subject. When discrepancies are combined by position, the greatest percentage of change from the Experimental Phase to the Maintenance Phase occurred at Position 5 (115%). Other percentages ranged from totals of 30% (P2) to 66% (P1). With respect to individual subjects, Subject 3 demonstrated the greatest percentage of change across phases (120%). Subject 6 demonstrated the least percentage of change (9%). Other performances ranged from 37% (S5) to 90% (S2). Percentage of change in individual positions greater than 10% (either greater or fewer) were demonstrated by all subjects except S6.

Table 4-12

Differences in Proportion of Responses by Choice Position Between Phases

Experimental	Maintenance	Sums of Difference
Subject 1		
16 24 7 22 11 15	19 20 8 33 9 6	+3 - 4 + 1 +11 -2 -9
5	6	+1 Procedural Errors
Subject 2		
16 21 17 16 17 13	3 28 0 45 3 23	- 13 +7 -17 +29 -14 +10
1	0	-1 Procedural Errors
Subject 3		
4 20 4 48 9 14	46 35 6 9 0 1	+42 +15 + 2 - 39 -9 - 13
1	2	+1 Procedural Errors

Table 4-12--Continued

Experimental	Maintenance	Sums of Difference
Subject 4		
10 33 5 31 4 12	5 19 0 54 3 16	-5 -14 - 5 +23 -1 +4
4	4	0 Procedural Errors
Subject 5		
8 16 13 27 11 23	5 5 10 38 19 24	- 3 -11 -3 +11 +8 +1
2	0	-2 Procedural Errors
Subject 6		
8 22 8 23 17 22	8 19 10 21 20 23	0 -3 +2 -2 +3 +1
0	0	0 Procedural Errors

Note Expressed as percentages.

Performance differences between subject response choices and the computer standard are presented for both Experimental and Maintenance Phases in Table 4-13. The differences can be totaled and compared with regard to position or learner. The highest total difference from the computer standard during the Maintenance Phase was noted in Position 5 (94%). Other differences during the Maintenance Phase ranged from 48% (P6) through 72% (P2). Subjects 3 and 4 demonstrated the greatest individual differences from the computer standard (104% and 83%, respectively). Percentages for the remaining subjects ranged from 31% (S6) through 65% (S2). Percentages of change that were greater than 10% in either direction were exhibited by all subjects except S6. When differences between Experimental and Maintenance Phases are totaled across positions for each subject, the greatest change was exhibited by Subject 3 (116%) and the least, by Subject 6 (11%). These same relative positions are also visible in Table 4-14 wherein totaled differences, for responses above (positive) and below (negative) the computer standard are summarized. Subject 3 demonstrated the greatest difference between phases for both positive (16%) and negative (17.5%) responses. Subject 6 increased positive responses by .5% and decreased negative responses by 1.5%. These data are reaffirmed in the combined responses for these subjects (S3-33.5%; S6-2%). In summary,

Table 4-13

Response Choice Position Differences from Computer Standard - Maintenance

Experimental	Maintenance	Sums of Difference
Subject 1		
-2.0 +12.0 -7.5 + .5 -4.5 -3.5	+1.0 +8.0 -6.5 +11.5 -6.5 -12.5	3 4 1 11 2 9
Subject 2		
-2.0 +9.0 +3.5 -5.5 +1.5 -5.5	-7.0 +8.0 -14.5 +19.5 -10.5 +5.5	5 1 18 25 11 11
Subject 3		
-14.0 +8.0 -10.5 +27.5 - 6.5 - 4.5	+28.0 +23.0 -8.5 -11.5 -15.5 -17.5	42 11 2 39 9 13

Table 4-13--Continued

Experimental		Maintenance		Sums of Difference	
Subject 4					
-8.0	+21.0	-13.0	+7.0	5	14
-9.5	+9.5	-14.5	+33.5	5	24
-11.5	-6.5	-12.5	-2.5	1	4
Subject 5					
-10.0	+4.0	+13.0	-7.0	3	11
-1.5	+6.5	-4.5	+17.5	3	11
+4.5	+4.5	+3.5	+5.5	8	1
Subject 6					
-10.0	+10.0	-10.0	+7.0	0	3
-6.5	+ 1.5	- 4.5	- .5	2	2
+1.5	+3.5	+4.5	+4.5	3	1

Note. Expressed as percentages.

Table 4-14

Combined Response Choice Position Differences from Computer Standard Across Experimental and Maintenance Phases[a]

Subject	Phase	Number of trials	Positive[b]	Negative[c]	Combined
1	Maintenance	80	20.5	25.5	46.0
	Experimental	880	12.5	17.5	30.0
			8.0	8.0	16.0
2	Maintenance	80	33.0	32.0	65.0
	Experimental	800	27.0	13.0	40.0
			6.0	19.0	25.0
3	Maintenance	80	51.0	53.0	104.0
	Experimental	720	35.0	35.5	70.5
			16.0	17.5	33.5
4	Maintenance	80	40.5	42.5	83.0
	Experimental	720	30.5	35.5	66.0
			10.0	7.0	17.0
5	Maintenance	80	26.5	24.5	51.0
	Experimental	800	15.0	16.0	31.0
			11.5	8.5	20.0
6	Maintenance	80	16.0	15.0	31.0
	Experimental	880	16.5	16.5	33.0
			- .5	- 1.5	- 2.0

Note. [a]Expressed in percentages. [b]Greater than computer standard. [c]Fewer than computer standard.

increases above 10% were noted for Subjects 4 and 5; similar decreases were noted for Subjects 2 and 3.

Summary of Maintenance Phase

Data from the Maintenance Phase of this study were compared to those from the Experimental Phase with respect to accuracy, speed, and response choice position (See Table 4-15). During this phase, all subjects maintained performances that were comparable to those of the Experimental Phase, although all of their levels of accuracy deteriorated.

Five subjects exhibited longer response latencies in the three-choice condition during the Experimental Phase and this performance was repeated during the Maintenance Phase. Response latencies during the Maintenance Phase were not only longer with three choices but also increasing in length in comparison to the Experimental phase.

The numbers of correct responses per minute were higher with three choices during both phases. However, some performance deterioration was noted for all subjects in at least one experiment.

When response position data were considered across Experimental and Maintenance Phases, the highest percentage of change was indicated at Position 5 and the least at Position 2. Subject 3 exhibited the highest percentage of change and S6, the least.

Table 4-15

Differences Between Experimental and Maintenance Phase Performances

Subject	Experiment	Accuracy[a]	R. Latency[b]	Correct Movements[b]	Response Position[b]
1	1	- 5	+ 8/3	-23/3	
	2	- 25	+36/3	-63/3	0
2	1	- 15	+ 6/3	-61/3	
	2	+20	+43/3	+48/3	+10/6
3	1	- 5	- 3/3	-23/3	
	2	+15	+26/3	+35/3	+10/6
4	1	- 5	+10/3	-55/3	
	2	- 15	+11/3	+13/3	+50/3
5	1	- 15	+ 9/6	+ 5/3	
	2	+20	- 7/6	-48/3	+20/3
6	1	- 15	+12/3	+46/6	
	2	- 10	- 14/3	-48/3	+90/3

Note. [a]Expressed as percentages of performance superiority in the three-choice condition compared to the six-choice condition. [b]Expressed as percentages of performance gain or loss in either the three- or six-choice condition.

Summary of Results

Within the Experimental Phase, data were collected and analyzed regarding accuracy,:speed, correct movements per minute, learning (celerations), and response choice position (see Table 4-7). Five subjects were clearly more accurate with three choices and performed with longer response latencies. One subject was slightly less accurate with three choices and had response latencies that favored the three-choice condition to a lesser degree. All subjects performed with higher frequencies of correct responses with three choices.

Although the three-choice condition was clearly delineated by accuracy and speed data, this trend was less clear for celeration data. Superiority in either condition across experiments was not as distinctive. Subjects appeared to select response choices less often on the left side of the computer screen and more often on the right side (center and top), as measured by differences from the computer standard. Across both conditions and experiments, Subjects 3 and 4 demonstrated the highest percentages of difference (71% and 66%) from the computer standard. All other subjects selected response positions that differed from the computer standard within a range of 30% to 33%. During the Maintenance Phase, most subjects demonstrated losses in their levels of performance yet maintained higher percentages of accuracy and correct movements per minute in the three-choice condition. A majority of subjects not only maintained longer

response latencies with three choices, but also increased the ratio over the six-choice condition. The greatest difference from the computer standard was maintained at Position 5 and the subject who differed to the greatest degree remained Subject 3. In Chapter V, these results are discussed with implications for teachers, learners, and researchers.

CHAPTER V
DISCUSSION

The following discussion is organized in sections that correspond to the five experimental questions: accuracy of responding, speed of responding, learning, response choice position, and maintenance. The summative effects of the results of this investigation can then be applied to answer the major question about whether there were differences in learner performance in a three-choice as compared to a six-choice condition.

This current study was undertaken as an exploratory investigation to examine whether learners perform differently according to the numbers of choices in a matching-to-sample procedure. If differences did exist, and were of sufficient magnitude, then interpretations, in terms of future applications, would be merited. Additional research or teaching techniques in which alternative matching-to-sample procedures are used might be recommended. This discussion therefore continues with an interpretation of the findings in terms of the the overall matching-to-sample procedure and concludes with implications for future researchers, instructional designers, and consumers.

Research Findings

Particular emphasis is given to the findings with regard to accuracy and speed in the following sections for two reasons. First, subjects performed with greater accuracy with three choices while,

taking longer to do so, according to response latency findings. Second, subsequent calculations of learning over time (celerations) are based upon accuracy and speed. Further analysis and discussion of this relationship therefore is warranted. Brief discussions related to learning, response position, and maintenance are presented as a conclusion to this section.

Accuracy of Responding

In this investigation, subjects clearly demonstrated greater accuracy when given three choices. Maximum accuracy levels with six choices also never exceeded those with three-choices. The consistency with which learner accuracy in the three-choice condition surpassed that of the six-choice condition across subjects permits the conclusion that number of choices is a powerful variable that is functionally related to learner performance in the matching-to-sample procedure. These results are interpreted as supporting statements of Cumming and Berryman (1965) and Sidman (1987) regarding the importance of the number of choices as a variable in the matching-to-sample procedure.

Speed of Responding

The second criterion used to measure the degree of difference in learner performance was speed. Response latencies are often cited in behavioral studies as useful measures of conditioning and learning. In the matching-to-sample procedure, the measurement of the time between the subject's first touch to the sample and the second touch has been considered a specific measure of learner attention and learning (Cumming &

Berryman, 1961). Latencies are often omitted in the analysis of data and were incorporated into this study to supplement findings of accuracy.

When response latencies were ranked and median latencies noted, subjects demonstrated longer response latencies under the three-choice condition; this behavior was replicated across sessions and experiments. In Experiment 1, all subjects took longer to respond in the three-choice condition than in the six-choice condition. In Experiment 2, five subjects took longer to respond in the three-choice condition; one subject performed equally well under either condition. The median percentage of difference between conditions was 26% in Experiment 1 and 21% in Experiment 2.

Longer latencies with three choices were not a function either of the order of presentation or the position of the correct response; both were determined randomly by the computer program. The content (the 10 correct words and their accompanying five incorrect alternates) for each learner's three- or six-choice condition was also determined individually and randomly.

The computer program controlled the presentation of experimental sessions that were the same for each subject in terms of the sample words presented under each condition. In the six-choice condition, when the subjects pressed the sample in the center of the screen, six response choices appeared on the screen.

The sample, correct choice, and all five incorrect choices were always visible. Learners were required to look and remember up to seven pieces of information as their eyes moved from response choice to response choice. They were, however, less accurate when six response choices were visible. This finding appears to be in conflict with the idea that learners can efficiently process and retain in short-term memory groups of seven, plus or minus two (Miller, 1968). The use of these larger numbers of response choices may be open to question for use with with young learners who process visual information.

In the three-choice condition, subjects selected one correct choice from among three options: one correct choice and two incorrect choices. The two incorrect choices were randomly selected from among the five possibilities and, together with the correct choice, randomly placed in three of the six response positions. Although the one correct and five incorrect choices remained constant, the incorrect choices for each session in three-choice condition were randomly selected by the program. Therefore, the incorrect response choices that were available and visible to the learner in the three-choice condition varied from session to session. With three choices and only two of the five incorrect choices presented, learners may have needed more time to select the correct choice from remembered as well as visible options. It is possible that subjects took longer between touching the sample and the choice when they were choosing correctly as a function of this design feature of the computer program.

A second factor in the programming of the matching-to-sample procedure that may have affected response latencies was the fact that subject responding was not shaped in any way. When subjects responded incorrectly, the next picture was presented immediately. Subjects may have had less success with six choices as a consequence of reduced subject contact with correct responses. Their first experience with the correct choice, upon which subsequent performances were based, was a matter of chance. With three choices, that chance was one out of three (33%); with six choices, that chance was only one out of six (16.7%). When learners failed to find the correct choice from among the six choices, they may have simply been overwhelmed by the number of choices, become frustrated, failed to look at the six alternatives, given up, and pressed any response choice. This interpretation is supported by observations of subjects' behaviors during their responding. When given three choices, learners would frequently point towards each response choice in turn, often more than once, while talking aloud about their ongoing process of discriminating, remembering, eliminating, and selecting. In contrast, when given six choices, subjects tended to rapidly touch a response choice and say, "It is too hard" or "I can't remember". This latter behavior would be recorded as shorter response latencies that, in the six-choice condition, were associated with incorrect or inaccurate responding. These findings are in conflict with suggestions that learners can attend to up to 10 (Woodward, 1987) or 11 (Becker et al., 1975) items on a page. Both the

inconsistent presentation of incorrect choices in the three-choice condition and the lack of stimulus shaping may have contributed to longer response latencies in the three-choice condition and shorter latencies in the six-choice condition. Regardless of the cause, in the six-choice condition, learners had fewer opportunities to experience the success needed to reinforce correct responding. As there is no clear or obvious explanation for the results, the "give up" phenomenon under six choices is probably a good working hypothesis.

Correct Movements per Minute

While measures of accuracy and speed are useful, when considered separately, they may not provide true reflections of learner improvement or deterioration, or differences between learners. For example, learners with equal accuracies of 90% may, in fact, be demonstrating very different learning if, for example, both learners attain the same accuracy but one takes twice as long to do so. Similarly, learners with very rapid performances may not be exhibiting better performances if the number of correct responses is not also considered.

Effective learners must be able to respond both accurately and rapidly. This efficiency, or automaticity of responding, is required to progress from the first learning stage of acquisition to later stages of mastery and generalization. The development of many readiness, reading, and discrimination skills also requires accurate and rapid automatic responses. When efficiency (the

relationship between accuracy and speed) is expressed as the ratio of the number of correct responses to a measure of time, comparisons can then be made within and across learners, conditions, and measures of time. When the high levels of accuracy achieved at the expense of longer response latencies became apparant, analysis of this relationship seemed warranted.

Prior to a discussion of the findings for the number of correct responses per minute, the following point should be made. When the number of correct responses and measures of time are considered in combination as a ratio, four possibilities for subject performance exist: more accurate with faster speed, more accurate with slower speed, less accurate with faster speed, and less accurate with slower speed (see the first panel of Figure 5-1). Squares 1 and 2 represent two combinations of accuracy and speed that a subject might have exhibited with three choices in this study; more accurate performances with three choices have already been documented. Squares 3 and 4 represent the possible combinations with six choices in which less accuracy was achieved. Squares 1 and 2 depict the possibility of more correct responses per minute with both faster and slower response times. In the second panel, hypothetical scores of higher (12) and lower (4) accuracy and faster (3) and slower (6) speed are represented. When the results of these ratios are depicted in the third panel,

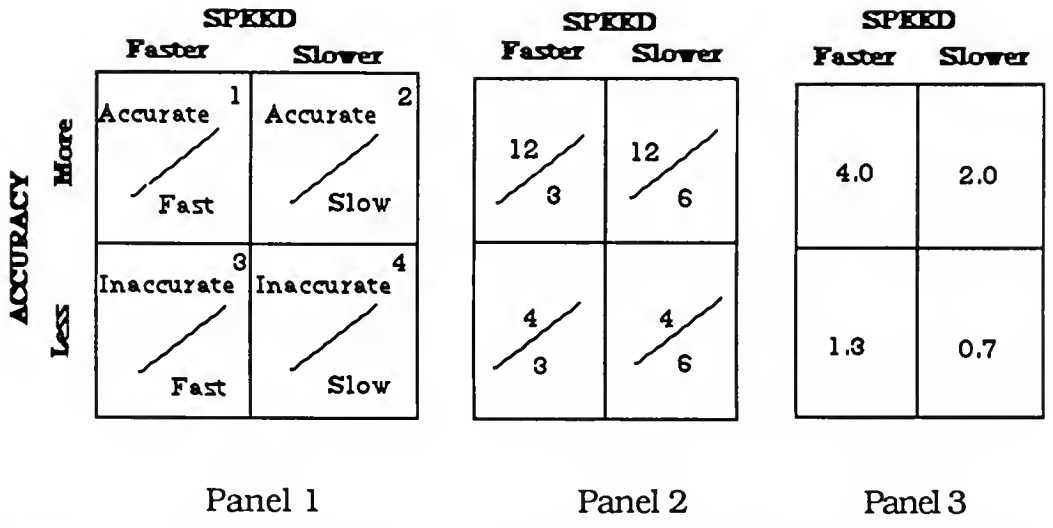

Figure 5-1. Hypothetical comparisons of speed and accuracy.

the "actual" possibility of more correct responses per minute with higher accuracy levels and slower speeds is graphically depicted. Square 2 represents results obtained in this study with three choices; Square 3 represents results with six choices. The possibility also exists for learners to achieve a higher frequency (2.0) of correct responses per minute when performances are more accurate and slower (Square 2) as opposed to a lower frequency (1.3) of correct responses per minute resulting from a performance that is less accurate and faster (Square 3).

In previous studies the association between longer response latencies and less accurate performances have been described. These studies did not, however, associate latency findings with frequencies (Cumming & Berryman, 1961, 1965; Nelson & Wasserman, 1978; Nevin, 1967; Nevin, Cumming, & Berryman, 1963). In addition, many of these previous investigations were

conducted with pigeons, not humans, and involved only two response choices. In this study, learners who demonstrated greater accuracy and longer response times with three choices, also demonstrated more correct responses per minute with three choices.

The critical point at which these ratios of accuracy to speed change with enough significiance to reverse findings of difference may be a function of response set size, time limitations, and the consequent ratio possibilities. That is, the limitations and the subsequent relative differences in size between the numerators and denominators may be critical. In this study, response sets were limited to 20 trials per condition; there were no time limitations. It therefore seems reasonable that variances in time might have provided the opportunity for greater ratio differences in this study. Subjects in this investigation were not restricted by time limits. Thus, the opportunity for learners to take advantage of longer periods of time before responding may have provided the critical factor for the establishment of more efficient (correct movements per minute) responding with three choices. The correlation between longer response latencies and more effective learning may be indicative of greater learner attention and more active involvement in the selection of the correct response in the three-choice condition. This premise would be supported by investigators who have stressed the importance of attention (Winslow & Etzel, 1972)

and involvement (Becker et al., 1975) of the learner. This premise would be contradicted by researchers who have advocated teacher-directed (computer-directed) or rapid-paced instruction (Engelmann & Carnine, 1982; Englert, 1984). The fact that accuracy, speed, and and frequency findings are consistent across learners and experiments contributes to the efficacy of the three-choice condition as a better structure for the implementation of matching-to-sample with young preschool learners.

One final point in relation to comparisons of speed and accuracy warrants discussion. Differences between the two conditions were described by median percentages of difference for accuracy and speed. Across experiments (1 vs. 2), medians that measured superiority with three choices were as follows: accuracy (15% vs. 18%), speed of responding (20% vs. 17%), and correct movements per minute (29% vs. 43%). The relative closeness of these measures across experiments extends the reliability of individual findings of the superior performance with three choices. The efficacy of median percentages of difference between conditions has also been demonstrated.

Learning was recorded by celerations and provided additional substantiation of the viability of the three-choice condition for young learners. Celerations greater than x1.00 are considered an indication of learning. In both experiments, more learning occurred in the three-choice condition than in the six-choice condition. With three choices, five subjects in Experiment 1 and four subjects in Experiment 2,

demonstrated celerations greater than x1.00. Results from Experiment 2 appear somewhat more favorable than those of Experiment 1 toward the three-choice condition as facilitating learning over time. This finding may be a further substantiation of the proposal made above that Experiment 1 may have provided an opportunity for practice. This practice would only be related to the procedure of matching-to-sample since the content of the response choices differed to a large and preplanned degree. Each experiment contained unique word sets.

Celeration data were less conclusive and supportive of the three-choice condition than the previously-discussed findings of accuracy and speed. This conclusion is based upon inconsistent performances across learners, experiments, and conditions. For example, some learners were able to improve learning with six-choices as well as three-choices. Results related to learning may be a reflection of the levels of maximum accuracy achieved by individual subjects in both experiments. While all learners were able to attain meaningful accuracy levels in the three-choice condition, these levels rarely exceeded 60%. Reasons for this ceiling effect on accuracy have been outlined below.

Position of Response Choices

The positions of response choices made by each subject were measured to provide a method for substantiating the validity of accuracy and speed findings. Previous matching-to-sample researchers have described instances when subjects have come

under the control of the position of the responses rather than the content of the stimuli. Responses can be either consistently present or absent from a particular response location and results are subsequently confounded. Two precautions were taken by the principle investigator. First, the organizational pattern of the sample and response choices was designed to reduce the possibility of position bias. Second, prior to initiating this investigation, a computer standard for placement of correct answers was determined against which comparisons of subject responses could be made.

Comparisons were made across conditions to determine whether the number of response choices had an effect on the learner's position of response. Subjects 1, 2, and 3 demonstrated greater discrepancies with the computer standard in the three-choice condition while Subjects 4, 5, and 6 exhibited the opposite behavior. Higher discrepancies for these subjects were noted in the three-choice condition. The results of this component were not consistent across subjects and are interpreted as indicating a lack of functional relationship between response position and experimental condition.

Results from this study have neither documented position bias nor reaffirmed previous findings in which an exhorbitant percentage of responses in one response position correlated with reduced performances in accuracy or speed (Cumming & Berryman, 1961; Iverson et al., 1986). High percentages of difference from the computer standard did not prevent two

subjects from performing with consistent superiority in the three-choice condition. Other subjects with comparatively low percentages also performed with consistent superiority in the three-choice condition.

Maintenance

Most subjects maintained accuracy levels in at least one experiment that were superior in the three-choice condition. These these levels indicated some loss of accuracy. Two subjects demonstrated increased accuracy in the three-choice condition during the Maintenance Phase. Measures of response latency were similar to those of the Experimental Phase. Most subjects demonstrated losses in the frequencies of corrects with three choices. When response choice data were considered during the Maintenance Phase, no remarkable differences from previous performances were noted. Three subjects increased differences from the computer standard with three choices; three subjects did so with six choices. Change across phases and differences from the computer standard for both positions and subjects during the Maintenance Phase mirrored previous performances. These findings lend further support to the interpretation that positions of response choice did not affect learning.

Two findings are notable when performances during the Maintenance Phase are considered. Higher levels of performance were retained in the three-choice condition, but some performance loss between the Experimental and Maintenance Phases was obvious. With regard to these performance during the Maintenance

Phase, three possibilities existed. First, subjects might have demonstrated improved performance in the three-choice condition beyond the levels of the Experimental Phase. This phenomenon is known as the Reminiscence Effect (W.D. Wolking, personal communication, July, 1987) and did not occur.

The second possibility existed that subjects might have reduced their levels of performance in the three-choice condition to such a degree that performance in the six-choice condition was superior during the Maintenance Phase. It had been hypothesized that if this change were to occur, it might have been the result of the six-choice condition providing the learner with more experience with incorrect choices. However, subjects spent less time with six choices, as substantiated by the response latency data, described above.

The third possibility occurred. Subjects retained their superior performance in the three-choice condition, yet demonstrated losses in the levels across phases. The durability of subject superiority in the three-choice condition may have been due to several factors: the validity the superiority of the three-choice condition during the Experimental Phase or the continued lack of student attention to the choices in the six-choice condition. The fact that students demonstrated loss was most probably the result of forgetting. Emphasis of one final point regarding the interpretation of the maintenance data is needed. The use of the final three sessions of the Experimental

Phase for comparison of with the Maintenance Phase was based on the assumption that these session would be representative of overall performance during that phase. As noted in the discussion of findings based upon celeration data, subjects did not always demonstrate consistency in their day-to-day learning. Therefore, data across the total Experimental Phase were used as a basis for comparison with Maintenance Phase data on response choice.

Experimental Questions

Major findings and points of interest have been discussed above. Based upon these discussions, the following answers are provided to the related questions posed in Chapter 1.

First, the number of response choices affected accuracy during the acquisition of stimulus control. Across experiments, all learners performed with greater accuracy with three choices.

Second, the number of response choices affected speed during the acquisition of stimulus control. Across experiments, all learners performed with slower speed (longer latencies) with three choices.

Third, the number of response alternatives affected learning (celeration) during the acquisition of stimulus control. Although subjects demonstrated greater ability to learn in the three-choice condition, these differences were not as consistent as the measures of accuracy and speed across conditions, experiments, or subjects.

Fourth, the number of response alternatives did not clearly affect response choice position. Across experiments, choices across panel positions were similar under both conditions.

Fifth, the number of response alternatives affected learning performance during the followup phase. Maintenance Phase data were generally consistent with the Experimental Phase findings, but showed the expected decrement in performance. In general, losses were noted at 15% in accuracy, with somewhat larger losses in speed.

These findings have provided the foundation upon which the answer to the primary question of this study can be based. The major question was posed to determine whether young students would perform better on a matching-to-sample task with three choices or six choices. As measured by accuracy and speed, clear differences did exist. All subjects, across experiments, performed with greater accuracy, and longer latencies in the three-choice condition. The additional analysis of frequencies substantiated more correct movements per minute with three choices. All subjects demonstrated greater learning (celeration) with three choices, although these data were less consistent. Measurements of learner performances during the Maintenance Phase have also supported superior performances in the three-choice condition. These factors have provided the primary investigator with sufficient evidence to conclude that the three-choice condition produces more effective learning than the six-choice procedure with preschool-aged learners using the matching-to-sample procedure.

Research Implications

The conclusion has been reached that the three-choice condition is generally superior; the problem now becomes one of judging whether differences in the number of choices were of sufficient magnitude to warrant recommendations to future researchers and instructional designers with regard to the matching-to-sample procedure. The experimental findings of this investigation have extended the body of knowledge regarding matching-to-sample procedural variables. The knowledge that three choices are preferable to six choices with young learners may be an important feature to be incorporated into the design of instructional materials for the classroom. This study also narrowed the gap between the classroom and applied research by demonstrating the feasibility of the microcomputer as a research and instructional tool. These findings can therefore be interpreted in terms of their applicability to both research and instruction. This process may provide a foundation upon which to build a feasible and reliable instructional strategy with applications to students of varied ages and discriminative ability, to other types of readiness tasks (color, shape, number, etc.) and to other modalities.

Matching-to-Sample

The learner. The success of the matching-to-sample procedure has been based upon a balance of learner looking and and responding. In this study, learners were able to look at visually

detailed information, skills that have been documented by Brinker (1984) and Clark-Stewart and Koch (1983). After making very difficult discriminations, they were also able to make accurate responses. The non-examples presented at each trial were designed to be particularly difficult for young learners to discriminate (Cohen & Gross, 1979). Engelmann and Carnine (1982), as well as Moore and Goldiamond (1964), have indicated that the role and number of non-examples is extremely important in discrimination learning. Findings from this study have led the investigator to conclude that, for preschool-aged learners, this range is from two through four non-examples.

Learners performed better with three choices despite the fact that the presentation of non-examples was not controlled. The two non-examples varied from session to session from among the five possible alternate non-examples. This design component may have been related to the fact that learners never achieved maximum levels of performance higher than 65% in either experiment. Learners were not able to discriminate between one example and five non-examples (six choices). The large number of non-examples present in the six-choice condition was apparently overwhelming for young learners, as demonstrated by faster response latencies.

While the subjects looked over the choices, potentially distracting behaviors such as scratching, talking, and sneezing also occurred. During both three- and six-choice conditions, subjects

participated in behaviors such as these, ignored other potential distractors caused by external sources, and were still able to respond accurately and efficiently with three choices. This ability to concentrate substantiates earlier findings of Winslow and Etzel (1972) with regard to the ability of young learners to attend to difficult tasks over many learning trials.

Learners were able to look and remember while using the matching-to-sample procedure. They could learn better with three as opposed to six choices. This finding is not similar to earlier findings in which numbers larger than six are proposed as acceptable for visual presentation (Becker et al., 1975; Miller, 1968; Woodward, 1987). In previous studies, higher numbers of choices have been suggested with regard to the number of items on a page or panel or screen. These researchers have not used the matching-to-sample procedure, nor always been concerned with the acquisition of new knowledge.

Consideration must also be given to the numbers of opportunities to learn as advocated by Harlow (1959) and Carnine (1980). The provision of a wide range of examples/opportunities may have prevented students from forming misconceptions and contributed to the understanding of the abstract relationship between the word and the picture. In this study, subjects had no difficulty attending to and implementing the matching-to-sample procedure successfully in as many as 80 trials during one sitting.

Finally, in this study, preschool-aged subjects were able to use the microcomputer successfully. This finding is in concordance with

with findings of other researchers who have advocated the use of microcomputers with young (Brinkley & Watson, 1986) or handicapped (Torgeson, 1986) learners. The appropriateness of the touchscreen as a mode for response with young learners, as suggested by Rettig (1986a), was also verified. The use of computer graphics in association with vocabulary words that are in the repetoire of preschool learner was also substantiated. More specifically, the viability of the microcomputer as a tool for the implementation of the matching-to-sample procedure in the classroom setting, as advocated by LeBlanc et al. (1985), was demonstrated.

The procedure. Several findings with regard to the procedure of matching-to-sample have been demonstrated. The results of this study clearly demonstrate that three choices are more effective than six. Previous work has established the need for using more than two choices (Cumming & Berryman, 1968; Sidman, 1987). By doing so, researchers may be able to reduce the number of unwarranted conclusions (Iverson et al., 1986); learners may be able to increase the opportunities for true selection by choice. Three choices work and also eliminate choice by exclusion or simple selection of the other choice. If the six-choice procedure had been used exclusively, learners would have become increasingly frustrated as they repeatedly attempted to match six words to a picture over repeated trials. Fewer than six choices have been demonstrated as more efficient with young learners.

The appropriateness of the matching-to-sample procedure as a tool for teaching new and abstract concepts to young learners has also been demonstrated. Learners were able to successfully match graphic representations of pictures to printed (abstract) words as has been demonstrated with older learners by Sidman et al. (1974). Using matching-to-sample, all subjects were able to learn, accurately and efficiently with three choices, a set of difficult symbolic relationships in 9 through 11 days.

The overall visual organization of sample and comparison choices in an equidistant circular pattern, as used by Sidman and others with older subjects, has also been substantiated. Similar pattern organizations had been suggested by Fleming and Levie (1978) and documented by Vernon (1952) as more conducive to learning by the reduction of response position bias.

Future research. As a result of this investigation, several considerations for the design of future matching-to-sample studies are noted. The highest accuracy scores achieved by individual learners ranged from 40% through 60% in the three-choice condition and from 45% through 65% during the six-choice condition. These percentages are in contrast to other matching-to-sample studies with young learners in which accuracy levels of 100% have been documented (Joyce & Wolking, in press). The lower levels of accuracy achieved by subjects in this study may have been a function of the content of the nonexamples. Incorrect response choices (words) used in this study were designed to be particularly difficult--given the age of the subjects, the proclivity of young

learners to make the types of errors contained in the nonexamples, and the size of the words on the computer screen. The fact that higher percentages were achieved during the second experiment and that no subject achieved higher than 65% accuracy may be a reflection of the difficulty of the task, the sequencing of the experiments, the design of the procedure, or the numbers of trials per condition. Subjects may have performed with slightly higher levels of accuracy on the second experiment as a result of having had the experience of the first experiment. This finding would support previous studies in which the importance of practice and review have been documented (Woodward, 1987). A limitation on the possibility of higher accuracy scores may have been imposed by the numbers of trials and reinforcements. As subjects were not reinforced nor shown the correct response when they responded incorrectly, their first selection of the a correct answer was based on chance. In future studies, the number of individual trials or word presentations per condition might therefore be reduced during experimental or instructional sessions in which new material is introduced. Previous studies by Kelly et al. (1986) have also documented the importance of limiting instructional sets.

Frequencies of correct responses per minute were used to compare performances across conditions and experiments. This procedure proved useful and provided a measure of the consistent superiority of the three-choice condition. It would not be premature to suggest that the measurement of the number of correct movements per minute should be included in future matching-to-sample research

and applications. Measures of speed added variability to the accuracy measures and expanded the possibilities for more indepth interpretations. For example, the apparent discrepancy between measures of response latency and measures of accuracy could be explained by the consideration of accuracy and speed together. The critical point at which longer response latencies become associated with inaccurate performances would be also an appropriate topic for future investigations. It is also possible that longer response latencies were associated with reduced maximum levels of accuracy in this study.

Because response latencies provide a measure with which to compute indepth analyses of subject behavior, their incorporation into future research is warranted. The opportunity exists for teachers, learners, and computer programs to limit the length of these latencies. Whether such control would have an effect on the acquisition of stimulus discriminations remains a topic for future research.

Those concerned with the measurement of learner efficiency would be advised to consider including celeration measures in programs in which no teaching component is included. On the other hand, designers concerned with the documentation of learner performance over time, in products designed either for remediation or for review, should consider the inclusion of celeration measures. Celeration measurement goes beyond typical "before" and "after" measure by using all data

points to determine the trend of learning. For researchers and designers concerned with the measurement of more than one episode of learner behavior, the use of celerations could provide a functional measure that is not often included in typical software packages.

Researchers and software designers should also provide for the documentation of response choice position in the design of their programs and the collection of data. This procedure can help ensure that the correct response will be placed in each position an equal proportion of the time by the computer program. In addition, the documentation of subject response may at some point provide evidence for otherwise unexplainable subject performances. During instructional sessions, designers might refine the procedure further and reduce the potential for procedural errors by recycling the learner back through the initial stages of instruction before continuing with more advanced material. A procedure such as this would be supported by Woodward (1987) and Kameenui et al. (1984) who have documented the success of cyclical and progressive levels of instruction.

Future reseachers might also consider investigating the following topics: the degree of acceptable position bias; the relationship between position bias and response latency or attention; the role of learner handedness or the ability to cross the midline in determining response choices; the relationship between error types and the position of response choices; and,

finally, the use of the Hyper-card, a computer program, (Apple) and the Macintosh computer (Apple).

Effective Instruction

Technologies such as microcomputing are capable of integrating effective teaching techniques with the principles of instructional design. Proponents of effective teaching have advocated the use of large numbers of examples, modeling, monitored independent practice, highly interactive instruction, checking for understanding, and a brisk pace. Instructional designers consider good examples, explicit strategies, controlled sequencing of skills, an adequate range of examples, practice for discrimination, cumulative review, and corrective feedback to be important instructional components. The manner in which any of these components are merged should rest on an empirical foundation.

As we have just entered an age of rapid technological development for instructional delivery, it is crucial that instructional designers, behavior analysts, and consumers (teachers and learners) be active participants on the instructional design team. With the use of microcomputers in both the laboratory and and the classroom, the roles of these individuals now be interchanged; suggestions that follow may therefore be useful to all members of this team.

Researchers. Further definition of the limitations of larger numbers of choices with young learners is needed. Research in this area should be expanded to include other types of classrooms,

learners, and tasks. Measures of learner performance should include those of accuracy, number of correct and error movements per minute, response latency, and response position as researchers become able to consider how big a difference is of practical significance. Celeration measures may not be implicated in programs that do not correct or branch to instruction when errors are made.

Instructional designers. The empirical findings of research with matching-to-sample, as in this study, should provide guidelines for the authoring of instructional software. Variations in the manner of reinforcement, the inclusion of stimulus shaping, and remediation strategies might facilitate quicker exposure to correct response choices and the possibility of using larger numbers of choices with young learners. Auditory or visual prompts might be provided when learners delay their first touch to the sample following its presentation. Teachers and students might be given varied amounts of control of the amount, rate, or organization of presentation (Torgeson, 1986).

The persistent difficulty that preschool children and learning disabled students have with the development of stimulus discrimination may be reduced with the matching-to-sample procedure in combination with systematic discrimination practice between stragegies (Darch, Carnine, & Gersten, 1984). A new skill (strategy) is introduced, practiced, then incorporated into instructional sets that contain other types of similar problems. As learners demonstrate higher

levels of accuracy and speed, known words are removed from the instructional set and incorporated into cumulative reviews. The higher learning scores noted in Experiment 2 may have implications for the incorporation of a "warmup" period into the design of instructional software, as suggested by Woodward (1987).

With computer-assisted instruction, there is the potential danger that exhorbitantly large amounts of material and massed practice may be provided, simply because it is possible. In this study, the limited amounts of information that are effective with young learners have been observed. Possible boredom, inattention, and frustration, which may be present with too much information, was illustrated in this study by less effective learning with six choices. In contrast, Woodward (1987), based upon Miller's work (1968), has suggested that seven is the ideal number with review material. More specifically, the results of this study would suggest that a designer provide fewer than seven items.

Young subjects were able to handle moderate amounts of information that was difficult, and they did so fairly gracefully and independently. Programs that can systematically fade guidance as students begin to function with greater skill may be more appropriate for these young learners. When needed, correction procedures, such as those suggested by Kameenui et al. (1986), that recycle a student back through the initial stages of

instruction could be provided. At all stages of learning, immediate feedback should be available to the student.

Future directions might also include the use of interactive videodisc technology, which is especially appropriate for instruction with visual material (Ferster & Perrott, 1968). This technology can be use to take advantage of the thousands of words that young children know during their preschool years to begin reading instruction with matching-to-sample. The possibility of motion expands the number of words to include not only nouns, as used in this investigation, but also, verbs and words that describe emotions. Videodiscs can provide crossmodality prompting with true sound. (audio-prompting of a correct choice) should might result in accelerated rates of acquiring new discriminations.

Subjects were successful with relatively large numbers of opportunities to learn (80 trials) within a touching procedure that was identical across trials, conditions, and experiments. This success has substantiated suggestions for software development that large learning sets in which the method of instruction is repeated contribute to efficient learning (Carnine, 1980; Woodward, 1987).

In summary, software can be designed that corrects, branches, and instructs. Measurements of accuracy, correct movements per minute, sample and response latencies, and celerations can provide precise documentation of individual progress across time. Random placement of response choices and

correct answers can be under the control of the computer program and reduce the possibility of interference from position bias. Greater flexibility can be given to teachers and students with regard to choices and times and provide the opportunity to develop instruction that is individually appropriate.

Consumers. The matching-to-sample procedure can be implemented in the classroom. Mackay (1985) and Etzel and LeBlanc (1979) have suggested that research and learning via this procedure, once reserved for the experimental laboratory, can now be offered to many more types of learners. The flexibility of scheduling various learners across the instructional day was apparent during the implementation of the data collection component of this study. With young learners especially, this type of flexibility is an exceptional instructional advantage. The range of languages spoken by the subjects in this study as well as the successful implementation of both Spanish and English written vocabulary indicated that the procedure has applicability as both a research and instructional technique across languages. For those students with limited English proficiency, this might be a valuable instructional tool. Finally, the ability of these young subjects to function and learn independently has implications for more efficient use of classroom teacher time.

Summary

This was a study of the influence of the number of choices on various aspects of performance with young learners. In the matching-to-sample procedure, three choices were more effective than six choices.

This was a study that was implemented via a software program based on empirically-based instructional design features, a microcomputer, and a touchscreen. The successful use of these tools suggests that they are viable options for both the researcher and teacher of young children.

This was a study that was implemented in an educational setting. The success of the investigation has implications for the continued use of the procedure and the tools in the classroom, by researchers and teachers alike.

Finally, this was a study that investigated discrimination learning with young students. Discrimination learning is typically difficult for both young learners and those students with special learning problems in the elementary years. The viability of the matching-to-sample procedure with three choices, the viability of the instructional tools, and the viability of the implementation with teachers and researchers in the educational setting suggest that, if pursued, these features might substantially broaden the instructional options available to instructional designers and teachers.

GLOSSARY

Computer-Assisted Instruction (CAI)--any combination of hardware and software that enables a student to interact directly with a computer on "academic" instruction.

Contingencies--relation between response and reward; without a correct response, no reward is provided.

Maintenance--the extent to which the learner continues to perform the target behavior after the termination of the intervention (Cooper, Heron, & Heward, 1987).

Matching-to-Sample--stimulus control procedure for occasioning, inhibiting, extending and maintaining behavior (Sulzer-Azaroff & Mayer, 1977).

Prompts--supplementary stimuli used to increase the likelihood that a correct response will be emitted in the presence of the natural discriminative stimulus that will eventually control the behavior (Billingsley & Romer, 1983; Snell, 1983). Prompts can be given before or during performance of behavior to help behavior to occur so reinforcement can be given.

Response Latency--the period that elapses between the presentation of the discriminative stimulus and the occurrence of the operant performance it controls. Changes in latency reflect conditioning (Ferster & Perrott, 1968).

Stimulus--any form of physical energy that is capable of being used in forming a relationship with behavior.

Stimulus Control--occurs when target behavior is emitted in the presence of a discriminative stimulus and never emitted in the absence of a stimulus or in the presence of an alternate stimulus. Further, alternative behavior is never emitted in the presence of the discriminative stimulus (Pryor, 1984).

Stimulus Discrimination--when a response is reinforced in the presence of one stimulus, there is no tendency to respond in the presence of new stimuli that have similar physical properties or have been associated with the stimulus. The response is not demonstrated in presence of new stimuli.

Stimulus Generalization--when a response is reinforced in the presence of one stimulus, there is a general tendency to respond in the presence of new stimuli that have similar physical properties or have been associated with the stimulus.

Stimulus Prompts--are given with task stimuli or instructional materials/cues to elicit correct response.

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APPENDIX A
PERMISSION AND INFORMED CONSENT FORMS

PLEASE READ INSTRUCTIONS ON THE REVERSE SIDE BEFORE COMPLETING THIS FORM.

UNIVERSITY OF FLORIDA INSTITUTIONAL REVIEW BOARD
(Committee for the Protection of Human Subjects)
114 Psychology Building

1. TITLE OF PROJECT: Matching-To-Sample in Young Children: Effects of the Numbers of Choices on Microcomputer Picture-Work Matching.
2. PRINCIPAL INVESTIGATOR: (Name, degree, title, dept., campus address and phone #)
Pamela Campbell, CAES, M. Ed., Doctoral Candidate, Special Education,
G315 Norman Hall 392-0755
3. SUPERVISOR: (Naame, campus address & phone #)
Dr. William D. Wolking, Special Education, G315 Norman Hall 392-0755
4. DATES OF ENTIRE PROPOSED PROJECT: From 6/4/87 to 7/30/87
5. NAME OF FUNDING (submitted) AGENCY: n/a

PLEASE EXPLAIN IN NON-TECHNICAL LANGAGE NO.'s 6, 7, & 8

6. SCIENTIFIC PURPOSE AND PROCEDURES OF THE INVESTIGATION: The purpose of this study is to compare the acquisition of picture/word matching skill when presented with three matches to the acquisition of the same skill when presented with six matches. Acquisition and maintenance are to be measured.

Procedures:
1. Develop a m,icrocomputer program to measure word and picture identification skills, and to present pcictures and words in three and six match formats.
2. Conduct pilot study with one subject and limited number of words.
3. Conduct screening to determine which subjects have mental ages between 3 years, months and 4 years, 6 months; are non-readers; able to match identical pictures; name and recognize pictures; and have IQs within the average range.
4. Select 6 subjects whose primary langage is English.
5. Using a microcomputer, monitor, and touchscreen, conduct sessions with alternate forms of matching-to-sample techniques to individual subjects for 40 trials. When 40 trials have been completed with English words, the procedure will be replicated with Spanish words for 40 trials.
6. Two weeks after the termination of the instructional sessions, one session of 80 trials will be held to measure maintenance of skills.
7. Initial sessions will be terminated when indicated by visual inspection of the data.
8. Selected sessions and the pilot study will be videotaped for analysis of procedural reliability.

7. ANTICIPATED RISK AND/OR POTENTIAL BENEFITS: (If subject is "at risk" steps taken to protect subject) No risks involved.
Benefits:
1. Studetns will gain increased skill in matching words to pictures.
2. Results may indicate on technique is more effective than the other.
3. Results may affirm the microcomputer as an instructional tool with young children who are non-readers.

8. MANNER OF OBTAINING SUBJECT, MONETARY COMPENSATION, NUMBER & AGE OF SUBJECT.
Children in a preschool in Alachua County will be screen for eligibility. No monetary compensation will be given. Sessions will be conducted by the principal investigator with a portabl micrcomputer system. Six subjects will be included in the study.

9. ATTACH A COMPLETED SAMPLE OF THE INFROMED CONSENT WHICH HAS BEEN PREPARED ACCORDING TO THE THE UFIRB GUIDELINES.

PLEASE USE ATTACHMENTS ONLY WHEN SPACE ON THE FORM IS INSUFFICIENT.

Signature: Principal Investigator

Signature: Supervisor

Parent And Student Informed Consent

In order to complete the requirements for a Ph.D. in special education, I have planned a study involving picture/word matching skills on a microcomputer. The ability to match words to pictures may be a useful strategy in learning to read. The participation of your child in the study would be very helpful.

The study compares two techniques to be used in the acquisition of matching skills. One technique involves the use of three word matches to one picture sample; the other method uses six word matches to one picture same. Pictures and words are presented on the computer screen; students respond by touching directly on the screen. I am interested in finding out whether students learn and retain the matching skill using these techniques. Hopefully the study will provide information regarding effective instruction for your child and his or her classmates.

The information obtained will be kept confidential to the extent provided by law. Your child's name will not be used in the written results. There is no risk involved and there will be no monetary compensation. You have the right to withdraw consent for your child to participate in the study at any time without prejudice.

If you have any questions about the study, please contact me at work (904-392-0755) or home (813-484-5880). I will gladly discuss this information in more detail.

Sincerely,

Pamela Campbell

I have read and understand the procedures described above, and agree to allow my child _____to participate in the picture/word matching project. I have received a copy of this description.

_____	_____	_____	
Parent or Guardian	Date	Witness/Second Parent	Date
_____	_____	_____	
Student	Date	Principal Investigator	Date

Script for Verbal Permission from Student

"Hello, (_____). I'm Pam. I would like you to
(student name)
play some games on the computer.

Would you like to play? _____
(response)

APPENDIX B
WORD RECOGNITION PRETESTS

WORD RECOGNITION PRETEST

Procedures:

Load disks, turn on computer. Select Language Choice from Menu. Select English. Select Word Recognition from Menu.

Instructions to subject:

"I *am going to show you some words on the computer. If you can, say the word when you see it. If you cannot say the word, say 'no'. Are you ready?"*

Goal: Identify 20 words that are unknown to the subject in either English or Spanish written form.

Part I. English Words

English word appears and remains in center of screen.

T: *"Say this word."* S says: *"no." or names word incorrectly.*

T: Record on Word Recognition Data Record.
Press <any key> for next word.
If subject does not say word after 5 seconds, repeat instructions. If subject says nothing, press <any key> for next word. Repeat procedure with next word.
When 20 unknown English words are identified, press <space bar> to return to Menu. If subject says word correctly, discontinue pretesting with this subject.

Part II. Spanish Words

Select Language Choice from Menu. Select Spanish. Select Word Recognition from Menu.

Spanish word appears and remains in center of screen.

T: *"Say this word."* S says: *"no." or names word incorrectly.*

T: Record on Word Recognition Data Record.
Press <any key> for next word.
If subject does not say word after 5 seconds, repeat instructions. If subject says nothing, press <any key> for next word. Repeat procedure with next word.
When 20 unknown Spanish words are identified, press <space bar> to return to Menu. If subject says word correctly, discontinue pretesting with this subject.

		WORD RECOGNITION DATA RECORD						
SUBJECT	Pilot	1	2	3	4	5	6	
ENGLISH								
bed								
apple								
boat								
box								
kite								
house								
comb								
key								
truck								
cup								
flag								
sword								
fork								
chair								
hammer								
star								
ladder								
knife								
table								
pencil								
SPANISH								
cama								
manzana								
barco								
caja								
cometa								
casa								
peine								
llave								
camion								
taza								
bandera								
expada								
tenedor								
silla								
martillo								
estrella								
escalera								
cuchillo								
mesa								
lapiz								

APPENDIX C
ENGLISH/SPANISH WORD LISTS

BASIC WORD LIST

English	Spanish	English	Spanish
acorn	bellota	cloud	nube
ant	hormiga	coat	saco
ape	monkey	comb	peine
apple	manzana	cow	vaca
apron	belantal	cup	taza
arm	brazo	deer	venado
axe	hacha	desk	escritorio
bag	saca	dish	plato
ball	pelota	dig	perro
balloon	globo	doll	muneca
banana	plantano	donkey	burro
barn	granero	door	puerta
basket	cersta	dress	vestido
bear	oso	drum	tambor
bed	cama	duck	pato
bee	abeja	ear	oido
bell	campana	egg	huevo
belt	cinturon	fairy	hada
bird	apjaro	fan	abanico
boat	barco	farm	granja
bone	hueso	father	padre
book	libro	finger	dedo
bow	lazo	fire	fuego
bowl	vasija	fish	paz
box	caja	flag	bandera
boy	muchacho	floor	piso
bread	panp	foot	pie
broom	escoba	football	fubol
brush	cepello	fork	tenedor
bug	insect	fox	zorro
butter	manteca	gate	entrada
cage	jaula	girl	muchacha
cake	torta	glass	vidrio
can	lata	goat	cabra
candle	vela	grapes	uvas
candy	dulches	grass	hierba
cane	gaston	gum	chicle
cap	gorro	hair	pelo
car	coche	hammer	martillo

BASIC WORD LIST (CONT.)

English	Spanish	English	Spanish
card	naipe	hanger	pistola
cat	gato	hat	sombrero
chalk	tiza	heart	corason
cheese	queso	heel	talon
chin	barba	helmet	yelmo
church	iglesia	hen	gallina
hill	colina	pin	alfiler
hook	gancho	puppy	perrito
horn	cuerno	rag	trapo
horse	caballo	rain	lluvia
hose	manguera	rake	rastro
house	casa	ribbon	cinta
jail	carcel	ring	anillo
jet	avion	road	camino
jug	jarro	robin	petirroho
key	llave	roof	techo
kite	cometa	rope	cuerda
kitten	gatito	rug	alfombra
knee	rodilla	ruler	somberano
knife	cuchillo	saw	sierra
ladder	escalera	school	escuela
leg	pierna	seed	semilla
letter	carta	shell	concha
light	luz	ship	barco
lips	labios	shoe	zapato
lock	cerradura	shovel	pala
man	hombre	sink	fregadero
mat	palleta	sled	trineo
match	fosforo	smoke	humo
milk	leche	snail	caracol
mitten	confortante	snake	culebra
mop	extropaho	snow	nieve
mother	madre	soap	jabon
mouth	boca	sock	clacetin
nail	clavo	spider	arana
napkin	servilleta	spoon	cuchara
neck	cuello	star	estrella
needle	aguja	steps	escalon
net	albanega	stick	palo
nose	nariz	stove	nornilla
nurse	enfermera	straw	paha
nut	nuez	sugar	azucar
owl	lechuza	swing	columpio

English	Spanish
pan	cacerola
peas	guisantes
pencil	lapiz
penny	centaro
pickle	slamuera
pie	pastel
pig	peruco
pillow	almohada
tub	tina
turkey	paro
turtle	tortuga
wagon	carreta
wall	pared
wallet	cartera
web	tela
sword	espada
table	mesa
tent	tienda
towel	toalla
toy	juguete
train	tren
tree	arbol
truck	camion
whale	bellena
window	ventana
wing	ala
wood	medera
worm	gusano
zipper	cremallera

English Words and Alternate Choices

	English	Last Letter	Internal	All/First Letter	First Letter	Total Reversal
1	bed	beb	bod	heb	ked	deb
2	apple	applo	aggle	olppa	opple	elppa
3	boat	boaf	baot	faob	doat	taob
4	box	bow	bex	zob	dox	xob
5	kite	kito	kife	otik	bite	etik
6	house	houso	huose	osuoh	bouse	esuoh
7	comb	comd	cemb	dmoc	oomb	bmoc
8	key	keg	koy	gek	bey	yek
9	truck	trush	trock	hcurt	lruck	kcurt
10	cup	cug	cop	guc	aup	puc
11	flag	flap	flog	palf	tlag	galf
12	sword	sworb	suord	brows	eword	drows
13	fork	forh	fkerk	brof	tork	krof
14	chair	chain	chiar	niahc	ohair	riahc
15	hammer	hammee	hanner	nemmah	bammer	remmah
16	star	stac	stor	nats	etar	rats
17	ladder	ladden	labber	neddal	tadder	reddal
18	knife	knifo	kmite	ofink	bnife	efink
19	table	tablo	todle	albat	fable	elbat
20	pencil	pencik	pemeil	ticnep	gencil	licnep

Spanish Words and Alternate Choices

	Spanish	Last Letter	Internal	All/First Letter	First Letter	Total Reversal
1	cama	camo	cona	omac	oama	amac
2	manzana	manzano	mamxano	onaznam	nanzana	anaznam
3	barco	barca	baneo	acrab	darco	ocrab
4	caja	caje	caga	ejac	oaja	ajac
5	cometa	comete	conota	otemoc	eometa	atemoc
6	casa	caso	coca	esac	oasa	asac
7	peine	peino	poime	aniep	geine	eniep
8	llave	llavc	llowe	avall	tlave	evall
9	camion	camiom	canton	moimac	oamion	noimac
10	taza	tazo	toxa	ezat	faza	azat
11	bandera	bandero	bambera	orednab	dandera	arednab
12	espada	espade	esgoda	sdapse	ospada	adapse
13	tenedor	tenedon	temodor	nodenet	fenedor	rodenet
14	silla	sillo	sitta	ollis	eilla	allis
15	martillo	martille	manlillo	allitram	nartillo	ollitram
16	estrella	estrellc	estnolla	ellertse	ostrella	allertse
17	escalera	escalero	escotera	orelacse	oscalera	arelacse
18	cuchillo	cuchille	cuebillo	allihcuc	ouchillo	ollihcuc
19	mesa	meso	moca	osem	nesa	asem
20	lapiz	lapix	lagtz	xipal	tapiz	zipal

APPENDIX D
PICTURE NAMING AND RECOGNITION PRETESTS

PICTURE NAMING AND RECOGNITION PRETESTS

Goal: Identify 20 pictures of previously identified words that subject can see/say and hear/point.

Part I. Picture Naming

Goal: See/say 20 pictures.
Procedures: Select Picture Naming from Menu.
Instructions to subject:

> *"I am going to show you some pictures on the computer. If you can, say the name of the picture when you see it. Are you ready?"*

Computer presents picture in the center of the screen.

T: *"What is this?"* S: Says: */picture name/.*

T: Record as correct on Picture Naming and Recognition Data Record. Press <any key> for next word.
If subject does not Say picture name after 5 seconds, repeat instructions.
If subject does not say word, show corresponding picture on 3x3 card and repeat instructions.
If subject correctly names picture on card, ask the subject to name the picture on the computer screen.
If subject correctly names the picture on the computer screen, press <any key> for next picture.
If subject does not say the name of the picture on the 3x3 card, provide auditory cues for the subject as follows:

We sleep in a _____.
It's fun to eat a shiny red _____.
We sail on the water in a _____.
You can put your toys in a toy _____.
When the wind blows, you can fly a _____.
Some people live in a _____.
To fix our hair, we use a brush and _____.
To unlock a door, we use a _____.
We see this on the highway. It is big, has lots of wheels makes a loud noises. It is a _____.
Sometimes, we drink from a _____.
When you watch a parade, you might see a _____.
A person could fight with a sharp _____.

PICTURE NAMING TEST (cont.)

To eat your dinner, you need a spoon or a _____.
You sit in a _____.
Pound the nail with a _____.
If you look up at the sky at night, you can see a ___.
To climb up high, use a _____.
To cut your food, use a _____.
You eat your dinner at a _____.
To write your name, you need a _____ .

If subject cannot name the word, discontinue pretesting with this subject.
If subject can name the word, return to pretesting with the computer.
When subject is able to correctly name 20 pictures in consecutive order, press <space bar> to return to Menu.

Part II. Picture Recognition

Goal: Hear/point point to 20 pictures.Each of the 20 pictures identified in the Picture Naming Pretest will be presented in an array containing 3 other randomly selected pictures. Target pictures will be presented in random order.

Procedures: Select Picture Recognition from Menu.
Record subject responses on Picture Naming and Recognition Data Record

Instructions to subject:

"You will see four pictures on the computer screen. I am going to say the name of one picture. If you can, touch the picture with your pointer finger when you hear its name. [Model "pointer finger" if necessary.] Are you ready?"

Computer presents a 2x2 picture array.

T: *"/picture name/".* S: *Touches picture.*
T: *"Good."*

Record as correct on Picture Pretest Data Record. Press <any key> for next array.

If subject does not touch the correct picture after 5 seconds, repeat instructions.
If subject does not touch the correct picture, repeat procedures in Part I: Picture Naming Pretest (3x3 cards and sentence completion, as necessary).
If subject does not touch the correct picture, stop pretesting with this subject.
Stop Picture Recognition Pretest when 20 pictures have been correctly identified.

PICTURE NAMING AND RECOGNITION DATA RECORD									
			PILOT	S1	S2	S3	S4	S5	S6
PICTURE NAMING									
1		bed							
2		apple							
3		boat							
4		box							
5		kite							
6		house							
7		comb							
8		key							
9		truck							
10		cup							
11		flag							
12		sword							
13		fork							
14		chair							
15		hammer							
16		star							
17		ladder							
18		knife							
19		table							
20		pencil							
PICTURE RECOGNITION									
1		bed							
2		apple							
3		boat							
4		box							
5		kite							
6		house							
7		comb							
8		key							
9		truck							
10		cup							
11		flag							
12		sword							
13		fork							
14		chair							
15		hammer							
16		star							
17		ladder							
18		knife							
19		table							
20		pencil							

APPENDIX E
MATCHING-TO-SAMPLE PRETESTS

MATCHING-TO-SAMPLE PRETESTS

Goal: To demonstrate that the subject can follow the matching-to-sample procedure.

Part I. Identity Matching (Cards)

Goal: See/touch stimulus picture (happy face) in center. See/match/touch target response (happy face) in rim, with increasing numbers of alternative responses: sad,confused,surprised,sleeping, and neutral faces. This pretest is designed to test the subject's ability to match identical pictures.

Procedures: Record responses on Identity Matching Data Record.

a. Center Only (Cards 1-2)

Goal: See/touch happy face (in center), 2 consecutive correct responses.

Instructions to subject:

T: "*You will see a face in the center of a card. When you see the face, touch the face with your pointer finger.*" [Model 'pointer finger' if necessary.] *"Are you ready?"*

Show card with happy face in the center of the card.

"Touch the face with your pointer finger."

S: Touches face.

T: *"Good. Touch the face with your pointer finger."*

S: Touches face.

T: *"Good."* Repeat as necessary until 2 consecutive correct responses are recorded.

b. Rim Only (Cards 3-8).

Goal: See/touch happy face (in rim); 6 consecutive corrects in each of 6 rim positions.

Instructions to subject:

T: "*You will see a face in the outside of the circle. When you see the face, touch the face with your pointer finger.*

[Model 'pointer finger' if necessary.] *"Are you ready?"*

Show card with happy face in the outside of the circle.

"Touch the face with your pointer finger."

S: Touches face.

T: *"Good. Touch the face with your pointer finger."*

S: Touches face.

T: *"Good."*

Repeat as necessary until 6 consecutive correct responses are recorded.

MATCHING-TO-SAMPLE PRETESTS (cont)

c. Center and Rim Matching (Target stimulus and response - no alternative choices) (Cards 9-14).

Goal: See/touch happy face in center.
See/touch/match happy face in rim); 6 consecutive corrects in each of 6 rim positions.

Instructions to subject:
T: *"You see a card with a face in the center. Touch it with your pointer finger. Then you will see faces on the outside edges. When you see a face on the outside edges that is the same as the face in the center, touch it with your pointer finger."* [Model 'pointer finger' if necessary.] *"Are you ready?"* Show card with happy face in the center. Give verbal cues only as needed.
"Touch the face with your pointer finger."
S: Touches face in center.
T: *"Good."* Reveal rim circles with one happy face on the rim.
"Touch the circle on the outside edge that is the same."
S: Touches matching face on rim.
T: *"Good."* Repeat with matching happy face in each of six rim positions. Continue until subject makes 6 consecutive correct touches, representing each rim position. If subject fails to touch either the center or rim positions, model correct procedure. Repeat from Step 1. If subject continues to fail, discontinue pretesting with this subject.

d. Center and Rim Matching (Target response/5 alternatives). (Cards 15-44, as needed).

Goal: See/touch happy face (in rim), 2 consecutive corrects in each of the 1-5 alternative choice sets.

Instructions to subject:
T: *"You will see a card with a face in the center. Touch it with your pointer finger. Then you will see faces on the outside edges. When you see a face on the outside edge that is the same as the face in the center, touch it with your pointer finger."* [Model "pointer finger" if necessary.] *"Do not touch any other pictures; touch on one time. Are you ready?"* Correct as necessary during this procedure until goal of 2 consecutive correct responses is reached for each set of alternative numbers of choices.

MATCHING-TO-SAMPLE PRETESTS (cont)

Set 1: 1 target response, 1 alternative response. (Cards 15-20, as needed)

T: Using masking card, show card with happy face in the center. *"Touch the face with your pointer finger."*
S: Touches face in center.
T: *"Good."* Remove masking card to reveal faces on rim (target happy face, one alternative face).
S: Touches target happy face on rim.
T: *"Good.""* Repeat as necessary until 2 consecutive correct responses are recorded.

Set 2: 1 target response, 2 alternative responses.(Cards 21-26, as needed)

T: Using masking card, show card with happy face in the center. *"Touch the face with your pointer finger."*
S: Touches face in center.
T: *"Good."*
T: Remove masking card to reveal faces on rim (target happy face, two alternative faces).
S: Touches target happy face on rim.
T: *"Good."* Repeat as necessary until 2 consecutive responses are recorded.

Set 3: 1 target response, 3 alternative responses.(Cards 27-32, as needed)

T: Using masking card, show card with happy face in the center. *"Touch the face with your pointer finger."*
S: Touches face in center.
T: *"Good."*
T: Remove masking card to reveal faces on rim (target happy face, three alternative faces).
S: Touches target happy face on rim.
T: "Good." Repeat as necessary until 2 consecutive responses are recorded.

MATCHING-TO-SAMPLE PRETESTS (cont)

Set 4: 1 target response, 4 alternative responses.(Cards 33-38, as needed)

T: Using masking card, show card with happy face in the center. *"Touch the face with your pointer finger."*
S: Touches face in center.
T: *"Good."*
T: Remove masking card to reveal faces on rim (target happy face, four alternative faces).
S: Touches target happy face on rim.
T: *"Good."* Repeat as necessary until 2 consecutive responses are recorded.

Set 5: 1 target response, 5 alternative responses.(Cards 39-44, as needed)

T: Using masking card, show card with happy face in the center. *"Touch the face with your pointer finger."*
S: Touches face in center.
T: *"Good."*
T: Remove masking card to reveal faces on rim (target happy face, five alternative faces).
S: Touches target happy face on rim.
T: *"Good."* Repeat as necessary until 2 consecutive responses are recorded.

Part II. Symbolic Matching (Microcomputer)

Goal: See/touch stimulus picture (lowercase letter) in center. See/match/touch target response (uppercase letter) in rim,with five of alternative (uppercase letter). This pretest is designed to test the subject's ability to match stimuli that are not visually identical yet belong to the same class.
Instructions to subject:
T: *"You will see a letter in the center of the screen. When you see the letter, touch the letter one time with your pointer finger."* [Model 'pointer finger' if necessary.] *"Then you will see letters on the outside edges. Touch the correct letter on the outside edge. Touch only once in the middle of the box. If you are correct, you will see a star blink above the correct letter. Try to make the star blink as many times as you can. Are you ready?"*

MATCHING-TO-SAMPLE PRETESTS (cont)

T: Select Letter Matching from Menu. Computer screen will show a lower case letter in the center of the screen. "Touch the letter with your pointer finger.
S: Touches letter.

Computer presents six boxes around the edges of the screen with one matching uppercase letter and 5 alternative uppercase letter choices.

T: *"Good touching. You remembered to touch one time in the middle of the box. Now touch the correct letter with your pointer finger."* Record responses on the Symbolic Matching Data Record.
S: Touches correct letter.
T: *"Good touching. You remembered to touch one time in the middle of the box and you touched the correct letter. Try to remember the match."* If subject does not touch the screen correctly, model correct touching procedure until subject can respond correctly. If subject touches screen correctly, gradually reduce verbal prompting. Repeat as necessary until 5 consecutive correct responses are recorded.

IDENTITY DATA MATCHING RECORD							
Subject	PILOT	S1	S2	S3	S4	S5	S6
Date							
SET A: 1-2							
SEE/POINT SD CENTER							
1							
2							
SET B: 3-8							
SEE/PT SD RIM - 6							
1							
2							
3							
4							
5							
6							
SET C: 9-14							
SEE/PT SD CTR/RIM - 6							
1							
2							
3							
4							
5							
6							
SET D-1: 15-20							
SEE/PT SD CTR + RIM - 1X							
1							
2							
SET D-2: 21-26							
SEE/PT SD CTR + RIM - 2X							
1							
2							
SET D-3: 27-32							
SEE/PT SD CTR + RIM - 3X							
1							
2							
SET D-4: 33-38							
SEE/PT SD CTR + RIM - 4X							
1							
2							
SET D-5: 39-44							
SEE/PT SD CTR + RIM - 5X							
1							
2							

	SYMBOLIC MATCHING DATA RECORD						
	PILOT	1	2	3	4	5	6
MATCH #							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
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30							

APPENDIX F
DATA COLLECTION PROCEDURES

DATA COLLECTION PROCEDURES

A. Learning Phase

If videotaping this session. Insert videotape into VCR. Turn on power pack, and VCR; focus camera; press play and record.

Prepare individual student disks by entering randomly selected words into either ther three- or six-choice condition. Prepare recording forms.

Insert individual student program disk into computer. Turn on computer and monitor. Select Language Choice from Menu. Select English.

Experiment I: English Words

Conditions (3/6) will be presented in random order as determined by computer program. Select Touch Game (1) from Menu. Wait while program is loaded into memory. Press down arrow one time to select "Start Game".

Give instructions as follows:

T: "*When you see a picture in the center of the screen, touch it with your pointer finger. Touch only one time and do not ouch anywhere else on the screen. After you have touched the picture in the center of the screen, you will see words on he edges of the screen. With your pointer finger touch the word that matches the picture. Touch on the word, inside the box. Do not touch any other place on the screen. If you are correct, a star will blink above the picture. Try to make the star blink as often as you can. Keep going until I tell you to rest.*"

Session 1: *"If you make the star blink, you can choose a sticker when you are all done."*

Subsequent sessions: *"If you make the star blink more often than you did yesterday, you can choose a sticker when you are all done."*

T: *"Are you ready?"*

Condition A (3 or 6 Choice)

The computer will present the first group of words in 20 trials of pictures and matching English words. Each of the 10 picture/word matches will be presented twice.

T: Begin timing when subject presses first picture in center of screen. Note on Recording Form whether three- or six-condition occurs first. With tally marks, record the position of each subject response on the recording form. End timing when "Stage 2" appears on the monitor screen. Enter total time for the first condition on subject's recording form.

DATA COLLECTION PROCEDURES (cont.)

Condition B (3 or 6 Choice)

The computer will present the second group of words in 20 trials of pictures and matching English words. Each of the 10 picture/word matches will be presented twice.

T: "Press the picture when you are ready." Begin timing when subject presses first picture in center of screen. With tally marks, record the position of each subject response on the recording form. End timing when summary screen appears on the monitor. On subject's recording form: enter total time for the second condition. On computer file screen: enter filename (Eng or Span/Session #), subject's last name, subject's firstname, session number ("2E"), experiment (first condition - 3 or 6), date [7/8/87]
Provide subject with opportunity to relax if necessary before continuing with Experiment II.

Press Control and Reset. Type "RUN MENU".

Experiment II: Spanish Words

Select Language Choice from Menu. Select Spanish. Conditions (3/6) will be presented in random order as determined by the computer program. Select Touch Game (1) from Menu. Wait while program is loaded into memory. Press down arrow one time to select "Start Game".

If needed, repeat instructions as follows:

T: "*When you see a picture in the center of the screen, touch it with your pointer finger. Touch only one time and do not touch anywhere else on the screen. After you have touched the picture in the center of the screen, you will see words on the edges of the screen. With your pointer finger touch the word that matches the picture. Touch on the word, inside the box. Do not touch any other place on the screen. If you are correct, a star will blink above the picture. Try to make the star blink as often as you can. Keep going until I tell you to rest.*"

Session 1: *"If you make the star blink, you can choose a sticker when you are all done."*

Subsequent sessions: *"If you make the star blink more often than you did yesterday, you can choose a sticker when you are all done."*

"Are you ready?"

DATA COLLECTION PROCEDURES (cont.)

Condition A (3 or 6 Choice)

The computer will present the first group of words in 20 trials of pictures and matching Spanish words. Each of the 10 picture/word matches will be presented twice.

T: Begin timing when subject presses first picture in center of screen. Note on Recording Form whether three- or six-choice condition occurs first. With tally marks, record the position of each subject response on the recording form. End timing when "Stage 2" appears on the monitor screen. Enter total time for the first condition on subject's recording form.

Condition B (3 or 6 Choice)

The computer will present the second group of words in 20 trials of pictures and matching Spanish words. Each of the 10 picture/word matches will be presented twice.

T: "Press the picture when you are ready." Begin timing when subject presses first picture in center of screen. With tally marks, record the position of each subject response on the recording form. End timing when summary screen appears on the monitor. On subject's recording form: enter total time for the second condition. On computer file screen: enter filename (Eng or Span/Session #), subject's last name, subject's firstname, session number ("2E"), experiment (first condition - 3 or 6), date [7/8/87]

Repeat with 5 additional subjects.

B. Maintenance Phase (1 session)
Insert individual student program disk into computer. Turn on computer and monitor.
Repeat Symbolic Matching Pretest
Select Letter Permutation from Menu.
See instructions (Appendix E).
Select Language Choice from Menu. Select English.
Repeat Experiment I: English Words
See above.
Save File as "Eng/Maint.
Repeat Experiment II: Spanish Words.
See above.
Save File as "Span/Maint.

Recording Form

Subject Name _____ Number _____

	Experiment 1				Experiment 2			
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	5
	3	6	3	6	3	6	3	6
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	5
	3	6	3	6	3	6	3	6
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	5
	3	6	3	6	3	6	3	6
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	5
	3	6	3	6	3	6	3	6
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	6
	3	6	3	6	3	6	3	6
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	6
	3	6	3	6	3	6	3	6
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	6
	3	6	3	6	3	6	3	6
Session__	__3	Time__	__6	Time__	__3	Time__	__6	Time__
Date:	1	4	1	4	1	4	1	4
	2	5	2	5	2	5	2	6
	3	6	3	6	3	6	3	6

BIOGRAPHICAL SKETCH

Pamela Campbell began her education in Melrose, Massachusetts, where she attended elementary, junior, and high schools. She earned a degreee in elementary education from the University of Massachusetts, at Amherst in 1972. In subsequent years, as a kindergarten teacher, special educator, and administrator of ESEA Chapter I programming, she expanded her knowledge across learners and settings. At the same time, she enrolled at Boston College where she received her M.Ed. in special education in 1980 and her C.A.E.S. in school psychology in 1982. Continuing to teach and consult in the public and private sectors, Pam developed skills in the areas of program development, assessment, instruction, management, and consultation.

In 1984, Pam began her doctoral program at the University of Florida where she has focused on the training of preservice teachers, programming for the at-risk student, mainstreaming for the special education student, and transition issues for the handicapped. An area of primary concern has been the use of the microcomputer as an instructional tool in ways that are based on the techniques of effective instruction and the principles of instructional design. Upon completion of the Ph.D. program, she will expand these and other interests by teaching teachers, conducting research, and writing.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

William D. Wolking, Chairman
Professor of Special Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Cecil D. Mercer
Professor of Special Education

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William R. Reid
Professor of Special Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Stuart E. Schwartz
Professor of Special Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Lee J. Mullally
Associate Professor of Instruction and Curriculum

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Elroy R. Bolduc
Professor of Instruction and Curriculum

This dissertation was submitted to the Graduate Faculty of the College of Education and to the Graduate School, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1987

Dean, College of Education

Dean, Graduate School

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